Steve Sturdy

Science Studies Unit
Uni of Edinburgh

A SYSTEM OF

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FIRST PRINCIPLES. VOL. II

# FIRST PRINCIPLES

BY

HERBERT SPENCER

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## THE KNOWABLE—*continued*

## CHAPTER XII

### EVOLUTION AND DISSOLUTION

§ 93. An entire history of anything must include its appearance out of the imperceptible and its disappearance into the imperceptible. Any account of an object which begins with it in a concrete form, or leaves off with it in a concrete form, is incomplete; since there remains an era of its existence undescribed and unexplained. While admitting that knowledge is limited to the phenomenal, we have, by implication, asserted that the sphere of knowledge is co-extensive with the phenomenal—co-extensive with all modes of the Unknowable which can affect consciousness. Hence, wherever we now find Being so conditioned as to act on our senses, there arise the questions—how came it to be thus conditioned? and how will it cease to be thus conditioned? Unless on the assumption that it acquired a sensible form at the moment of perception, and lost its sensible form the moment after perception, it must have had an antecedent existence under this sensible form, and will have a subsequent existence under this sensible form. And knowledge of it remains incomplete until it has united the past, present, and future histories into a whole.

Our daily sayings and doings presuppose more or less such knowledge, actual or potential, of states which have gone before and of states which will come after. Knowing any man personally, implies having before seen him under a shape much the same as his present shape; and knowing him simply as a man, implies the inferred antecedent states of infancy, childhood, and youth. Though the man's future is not known specifically, it is known generally: that he will die and decay are facts which complete in outline the changes to be gone through by him. So with all

objects around. The pre-existence under concrete forms of our woollens, silks, and cottons, we can trace some distance back. We are certain that our furniture consists of matter which was aggregated by trees within these few generations. Even of the stones composing the walls of the house, we are able to say that years or centuries ago, they formed parts of some stratum in the Earth. Moreover, respecting the hereafter of the wearable fabrics, the furniture, and the walls, we can assert thus much, that they are all decaying, and in periods of various lengths will lose their present coherent shapes. This information which all men gain concerning the past and future careers of surrounding things, Science continues unceasingly to extend. To the biography of the individual man, it adds an intra-uterine biography beginning with him as a minute germ; and following out his ultimate changes it finds his body resolved into certain gaseous products of decomposition. Not stopping short at the sheep's back and the caterpillar's cocoon, it identifies in wool and silk the nitrogenous matters absorbed by the sheep and the caterpillar from plants. The substance of a plant's leaves, in common with the wood from which furniture is made, it again traces back to certain gases in the air and certain minerals in the soil. And the stratum of stone which was quarried to build the house, it learns was once a loose sediment deposited in an estuary or on the sea-bottom.

If, then, the past and the future of each object is a sphere of possible knowledge; and if intellectual progress consists largely, if not mainly, in widening our acquaintance with this past and this future; it is obvious that the limit towards which we progress is an expression of the whole past and the whole future of each object and the aggregate of objects. It is no less obvious that this limit, if reached, can be reached only in a very qualified sense: inference more than observation must bring us to it. This garden annual we trace down to a seed planted in the spring, and analogy helps us back to the microscopic ovule whence the seed arose. Observation, verifying forecast, extends our knowledge to the flowers and the seeds, and afterwards to the death and decay which, sooner or later, ends in diffusion, partly through the air, partly through the soil. Here the rise of the aggregate out of the imperceptible and its passage back into the imperceptible is

indistinct at each extreme. Nevertheless we may say that in the case of this organism, as of organisms in general, the account, partially based on observation but largely based on inference, fulfils the definition of a complete history fairly well. But it is otherwise throughout the inorganic world. Inference here plays the chief part. Only by the piecing together of scattered facts can we form any conception of the past or future of even small inorganic masses, and still less can we form it of greater ones; and when we come to the vast masses forming our Solar System, the limits to their existence, alike in the past and in the future, can be known but inferentially: direct observation no longer aids us. Still, science leans more and more to the conclusion that these also once emerged from the imperceptible through successive stages of condensation and will in an immeasurably remote future lapse again into the imperceptible. So that here, too, the conception of a complete history is in a sense applicable, though we can never fill it out in more than an indefinite way.

But after recognizing the truth that our knowledge is limited to the phenomenal and the further truth that even the sphere of the phenomenal cannot be penetrated to its confines, we must nevertheless conclude that so far as is possible philosophy has to formulate this passage from the imperceptible into the perceptible, and again from the perceptible into the imperceptible.

This last sentence contains a tacit suggestion which must, however, be excluded. The apparent implication is that a confessedly imperfect theory may, by extension after the manner described, be changed into an avowedly perfect one. But we may anticipate that the extension will prove in large measure impracticable. Complete accounts of the beginnings and ends of individual objects cannot in most cases be reached: their initial and terminal stages are left vague after investigation has done its best. Still more, then, with the totality of things must we conclude that the initial and terminal stages are beyond the reach of our intelligence. As we cannot fathom either the infinite past or the infinite future, it follows that both the emergence and immergence of the totality of sensible existences must ever remain matters of speculation only—speculation more or less justified by reasoning from established data, but still—speculation.

Hence the conception of Philosophy above implied must be regarded as an ideal to which the real can never do more than approximate. Ideals in general—even those of the exact sciences—cannot be reached, but can only be nearly approached; and yet they, in common with other ideals, are indispensable aids to inquiry and discovery. So that while it may remain the aim of philosophy to give that comprehensive account of things which includes passage from the imperceptible into the perceptible and again from the perceptible into the imperceptible, yet it may be admitted that it must ever fall far short of this aim. Still, while recognizing its inevitable incompleteness, we infer that such approach to completeness as is possible will be effected under guidance of the conceptions reached in the last two chapters. That general law of the re-distribution of matter and motion which we lately saw is required to unify the various kinds of changes, must also be one that unifies the successive changes which sensible existences, separately and together, pass through between their appearance and their disappearance. Only by some formula combining these characters can knowledge be reduced to a coherent whole.

§ 94. Already in the foregoing paragraphs the formula is foreshadowed. Already in recognizing the fact that Science, tracing back the histories of various objects, finds their components were once in diffused states, and forecasting their futures sees that diffused states will be again assumed by them, we have recognized the fact that the formula must be one comprehending the two opposite processes of concentration and dispersion. And already in thus describing the general nature of the formula, we have approached a specific expression of it. The change from a dispersed, imperceptible state to a concentrated, perceptible state, is an integration of matter and concomitant dissipation of motion; and the change from a concentrated, perceptible state to a dispersed, imperceptible state, is an absorption of motion and concomitant disintegration of matter. These are truisms. Constituent parts cannot aggregate without losing some of their relative motion; and they cannot separate without more relative motion being given to them. We are not concerned here with any motion which the components of a mass have with respect to other masses: we are concerned only

with the motion they have with respect to one another. Confining our attention to this internal motion, and to the matter possessing it, the axiom which we have to recognize is that a progressing consolidation involves a decrease of internal motion; and that increase of internal motion involves a progressing unconsolidation.

When taken together, the two opposite processes thus formulated constitute the history of every sensible existence under its simplest form. Loss of internal motion and consequent integration, eventually followed by gain of internal motion and consequent disintegration—see here a statement comprehensive of the entire series of changes passed through: comprehensive in an extremely general way, as any statement which holds of sensible existences at large must be; but still, comprehensive in the sense that all the changes gone through fall within it. This will probably be thought too sweeping an assertion, but we shall quickly find it justified.

§ 95. For here we have to note the further all-important fact, that every change suffered by every sensible existence, is a change in one or other of these two opposite directions. Apparently an aggregate which has passed out of some originally discrete state into a concrete state, thereafter remains for an indefinite period without undergoing further integration, and without beginning to disintegrate. But this is untrue. All things are growing or decaying, accumulating matter or wearing away, integrating or disintegrating. All things are varying in their temperatures, contracting or expanding, integrating or disintegrating. Both the quantity of matter contained in an aggregate and the quantity of motion contained in it increase or decrease; and increase or decrease of either is an advance towards greater diffusion or greater concentration. Continued losses or gains of substance, however slow, imply ultimate disappearance or indefinite enlargement; and losses or gains of insensible motion will, if continued, produce complete integration or complete disintegration. Heat rays falling on a cold mass, augmenting the molecular motions throughout it, and causing it to occupy more space, are beginning a process which if carried far will disintegrate the mass into liquid, and if carried farther will disintegrate the liquid into gas. Conversely, the decrease of bulk which a volume of gas undergoes as it parts with

some of its molecular motion, is a decrease which, if the loss of molecular motion proceeds, will be followed by liquefaction and eventually by solidification. And since there is no such thing as a constant temperature, the necessary inference is that every aggregate is at every moment progressing towards either greater concentration or greater diffusion.

§ 96. A general idea of these universal actions under their simplest aspects having been obtained, we may now consider them under certain more complex aspects. Thus far we have supposed one or other of the two opposite processes to go on alone—we have supposed an aggregate to be either losing motion and integrating or gaining motion and disintegrating. But though every change furthers one or other of these processes, neither process is ever unqualified by the other. For each aggregate is at all times both gaining motion and losing motion.

Every mass, from a grain of sand to a planet, radiates heat to other masses, and absorbs heat radiated by other masses; and in so far as it does the one it becomes integrated, while in so far as it does the other it becomes disintegrated. In inorganic objects this double process ordinarily works but unobtrusive effects. Only in a few cases, among which that of a cloud is the most familiar, does the conflict produce rapid and marked transformations. One of these floating bodies of vapour expands and dissipates, if the amount of molecular motion it receives from the Sun and Earth exceeds that which it loses by radiation into space and towards adjacent surfaces; while, contrariwise, if, drifting over cold mountain tops, it radiates to them much more heat than it receives, the loss of molecular motion is followed by increasing integration of the vapour, ending in the aggregation of it into liquid and the fall of rain. Here, as elsewhere, the integration or the disintegration is a differential result.

In living aggregates, and especially in animals, these conflicting processes go on with great activity under several forms. There is not merely what we may call the passive integration of matter, which inanimate masses effect by simple molecular attractions, but there is an active integration of it under the form of food. In addition to that passive superficial disintegration which inanimate

objects suffer from external agents, animals produce in themselves active internal disintegration, by absorbing such agents. While, like inorganic aggregates, they passively radiate and receive motion, they are also active absorbers of motion latent in food, and active expenders of that motion. But notwithstanding this complication of the two processes, and the immense exaltation of the conflict between them, it remains true that there is always a differential progress towards either integration or disintegration. During the earlier part of the cycle of changes the integration predominates—there goes on what we call growth. The middle part of the cycle is usually characterized, not by equilibrium between the integrating and disintegrating processes, but by alternate excesses of them. And the cycle closes with a period in which the disintegration, beginning to predominate, eventually puts a stop to integration, and after death undoes what integration had originally done. At no moment are assimilation and waste so balanced that no increase or decrease of mass is going on. Even in cases where one part is growing while other parts are dwindling, and even in cases where different parts are differently exposed to external sources of motion, so that some are expanding while others are contracting, the truth still holds. For the chances are infinity to one against these opposite changes balancing one another; and if they do not balance, the aggregate as a whole is integrating or disintegrating.

Hence that the changes ever going on are from a diffused imperceptible state to a concentrated perceptible state, and back again to a diffused imperceptible state; must be that universal law of re-distribution of matter and motion, which serves to unify the seemingly diverse groups of changes, as well as the entire course of each group.

§ 97. The processes thus everywhere in antagonism, and everywhere gaining now a temporary and now an enduring predominance the one over the other, we call Evolution and Dissolution. Evolution under its most general aspect is the integration of matter and concomitant dissipation of motion; while Dissolution is the absorption of motion and concomitant disintegration of matter.

The last of these titles answers its purpose tolerably well, but the first is open to grave objections. Evolution has other mean-

ings, some of which are incongruous with, and some even directly opposed to, the meaning here given to it. The evolution of a gas is literally an absorption of motion and disintegration of matter, which is exactly the reverse of that which we here call Evolution. As ordinarily understood, to evolve is to unfold, to open and expand, to throw out; whereas, as understood here, the process of evolving, though it implies increase of a concrete aggregate, and in so far an expansion of it, implies that its component matter has passed from a more diffused to a more concentrated state—has contracted. The antithetical word Involution would more truly express the nature of the change; and would, indeed, describe better those secondary characters of it which we shall have to deal with presently. We are obliged, however, notwithstanding the liabilities to confusion resulting from these unlike and even contradictory meanings, to use Evolution as antithetical to Dissolution. The word is now so widely recognized as signifying, not, indeed, the general process above described, but sundry of its most conspicuous varieties, and certain of its secondary but most remarkable accompaniments, that we cannot now substitute another word.

While, then, we shall by Dissolution everywhere mean the process tacitly implied by its ordinary meaning—the absorption of motion and disintegration of matter; we shall everywhere mean by Evolution the process which is always an integration of matter and dissipation of motion, but which, as we shall now see, is in most cases much more than this.

## CHAPTER XIII

### SIMPLE AND COMPOUND EVOLUTION

§ 98. Where the only forces at work are those directly tending to produce aggregation or diffusion, the whole history of an aggregate will comprise no more than the approaches of its components towards their common centre and their recessions from their common centre. The process of Evolution, including nothing beyond what was described at the outset of the last chapter, will be simple.

Again, where the forces which cause movements towards a common centre greatly exceed all other forces, any changes additional to those of aggregation will be comparatively insignificant: there will be integration slightly modified by further kinds of re-distribution.

Or if, because of the smallness of the mass, or because of the little motion it receives from without in return for the motion it loses, the integration proceeds rapidly; there will similarly be wrought but insignificant effects by secondary forces, even though these are considerable.

But when, conversely, the integration is slow; either because the quantity of motion contained in the aggregate is relatively great; or because, though the quantity of motion which each part possesses is not relatively great, the large size of the aggregate prevents easy dissipation of the motion; or because, though motion is rapidly lost more motion is rapidly received; then, other forces will cause in the aggregate sensible modifications. Along with the change constituting integration, there will take place further changes. The Evolution, instead of being simple, will be compound.

These several propositions require some explanation.

§ 99. So long as a body moves freely through space, every force which acts on it produces an equivalent in the shape of some change in its motion. No matter how high its velocity, the slightest lateral traction or resistance causes it to deviate from its line of movement; and the effect of the perturbing influence goes on accumulating in the ratio of the squares of the times during which its action continues uniform. But when this same body is held fast by gravitation or cohesion, small incident forces, instead of giving it some relative motion through space, are otherwise dissipated.

What thus holds of masses holds, in a qualified way, of the sensible parts of masses, and of molecules. As the sensible parts of a mass, and the molecules of a mass, are, by virtue of their aggregation, not perfectly free, it is not true of each of them, as of a body moving through space, that every incident force produces an equivalent change of position: part of the force goes in working other changes. But in proportion as the parts or the molecules are feebly bound together, incident forces effect marked re-arrangements among them. Where the integration is so slight that the parts, sensible or insensible, are almost independent, they are almost completely amenable to every additional action; and along with the concentration going on there go on other re-distributions. Contrariwise, where the parts are so close that what we call the attraction of cohesion is great, additional actions, unless intense, have little power to cause secondary re-arrangements. The firmly-united parts do not change their relative positions in obedience to small perturbing forces; but each small perturbing force usually does nothing more than temporarily modify the insensible molecular motions.

How may we best express this difference in general terms? An aggregate that is widely diffused, or but little integrated, is an aggregate containing a large quantity of motion—actual or potential or both. An aggregate that has become completely integrated or dense, is one containing comparatively little motion: most of the motion its parts once had has been lost during the integration that has rendered it dense. Hence, other things equal, in proportion to the quantity of motion an aggregate contains will be the quantity of secondary change in the arrangement of

its parts that accompanies the primary change in their arrangement. Hence also, other things equal, in proportion to the time during which the internal motion is retained, will be the quantity of this secondary re-distribution. It matters not how these conditions are fulfilled. Whether the internal motion continues great because the components are of a kind that will not readily aggregate, or because surrounding conditions prevent them from parting with their motion, or because the loss of their motion is impeded by the size of the aggregate they form, or because they directly or indirectly obtain more motion in place of that which they lose; it throughout remains true that much retained internal motion renders secondary re-distributions facile, and that long retention of it makes possible an accumulation of such secondary re-distributions. Conversely, non-fulfilment of these conditions, however caused, entails opposite results. Be it that the components of the aggregate have special aptitudes to integrate quickly, or be it that the smallness of the aggregate permits easy escape of their motion, or be it that they receive little or no motion in exchange for that which they lose; it alike holds that but little secondary re-distribution can accompany the primary re-distribution constituting their integregation.

Let us, before studying simple and compound Evolution as thus determined, contemplate a few cases in which the quantity of internal motion is artificially changed, and note the effects on the re-arrangement of parts.

§ 100. When a vessel has been filled to the brim with loose fragments, shaking it causes them to settle down into less space, so that more may be put in. And when among the fragments there are some of much greater specific gravity than the rest, these, in the course of a prolonged shaking, find their way to the bottom. What are these results, expressed in general terms? We have a group of units acted on by an incident force—the attraction of the Earth. So long as these units are not agitated, this incident force cannot change their relative positions; agitate them, and their loose arrangement passes into a more compact arrangement. Again, so long as they are not agitated, the incident force cannot separate the heavier units from the lighter; agitate them, and the

heavier units begin to segregate. Mechanical disturbances of more minute kinds, acting on the parts of much denser masses, produce analogous effects. A piece of iron which, when it leaves the workshop, is fibrous in structure, becomes crystalline if exposed to a perpetual jar. The polar forces mutually exercised by the atoms, fail to change their disorderly arrangement into an orderly arrangement while they are relatively quiescent; but these forces succeed in re-arranging them when they are kept in a state of intestine motion. Similarly, the fact that a bar of steel, suspended in the magnetic meridian and repeatedly struck, becomes magnetized is ascribed to a re-arrangement of particles produced by the magnetic force of the Earth when vibrations are propagated through them. Now imperfectly as these cases parallel those we are considering, they yet serve roughly to illustrate the effect which adding to the quantity of motion an aggregate contains has in facilitating re-distribution of its components.

More fully illustrative are the instances in which, by artificially adding to or subtracting from the molecular motion called its heat, we give an aggregate increased or diminished facility of re-arranging its molecules. The process of tempering steel or annealing glass shows us that internal re-distribution is aided by insensible vibrations, as we have just seen it to be by sensible vibrations. When some molten glass is dropped into water, and its outside is thus, by sudden solidification, prevented from participating in that contraction which subsequent cooling of the inside tends to produce; the units are left in such a state of tension, that the mass flies into fragments if a small portion be broken off. But if this mass be kept for a day or two at a considerable heat, though a heat not sufficient to alter its form, this extreme brittleness disappears: the component particles being thrown into greater agitation, the tensile forces are enabled to re-arrange them into a state of equilibrium. Much more conspicuous is the effect of heat where the re-arrangement of parts taking place is that of visible segregation. An instance is furnished by the subsidence of fine precipitates. These sink down very slowly from solutions which are cold; while warm solutions deposit them with comparative rapidity. That is to say, exalting the molecular oscillation throughout the mass allows the suspended particles to separate

more readily from the particles of fluid. The influence of heat on chemical changes is so familiar that examples are scarcely needed. Be the substances concerned gaseous, liquid, or solid, it equally holds that their chemical unions and disunions are aided by rise of temperature. Affinities, which do not suffice to effect the re-arrangement of mixed units that are in a state of feeble agitation, suffice to effect it when the agitation is raised to a certain point. And so long as this molecular motion is not great enough to prevent those chemical cohesions which the affinities tend to produce, exalting it facilitates chemical re-arrangement.

Let us pass to illustrations of a different class. Other things equal, the liquid form of matter implies a greater quantity of contained motion than the solid form: the liquidity being itself a consequence of such greater quantity. Hence, an aggregate made up partly of liquid matter and partly of solid matter, contains more motion than one which, otherwise like it, is made up wholly of solid matter. It is inferable, then, that a liquid-solid aggregate, or, as we call it, a plastic aggregate, will admit of internal re-distribution with comparative facility; and the inference is verified by experience. While a magma of unlike substances ground up with water continues thin there goes on a settlement of its heavier components—a separation of them from the lighter. As the water evaporates this separation is impeded, and ceases when the magma becomes thick. But even when it has reached the semi-solid state in which gravitation fails to cause further segregation of its mixed components, other forces may still produce segregation: witness the fact that when the pasty mixture of ground flints and kaolin, prepared for making porcelain, is kept some time, it becomes gritty and unfit for use—the particles of silica separate themselves from the rest and unite into grains; or witness the fact known to every housewife, that in long-kept currant jelly the sugar takes the shape of embedded crystals.

No matter then under what form the motion contained by an aggregate exists—be it visible agitation, or such vibrations as produce sound, be it molecular motion absorbed from without, or the constitutional molecular motion ot some component liquid, the same truth holds. Incident forces work secondary re-distributions easily when the contained motion is large in quantity; and

work them with increasing difficulty as the contained motion diminishes.

§ 101. Yet another class of facts which fall within the same generalization must be named before proceeding. They are those presented by certain contrasts in chemical stability. Speaking generally, stable compounds contain but little molecular motion, and in proportion as the contained molecular motion is great the instability is great.

The most common and marked illustration of this, is that chemical stability decreases as temperature increases. Compounds of which the elements are strongly united, and compounds of which the elements are feebly united, are alike in this, that heating them or adding to the quantities of their contained molecular motion diminishes the strengths of the unions of their elements; and by continually augmenting the contained molecular motion, a point is in each case reached at which the union is destroyed. That is to say, the re-distribution of matter which constitutes simple chemical decomposition, is easy in proportion as the quantity of contained motion is great. The like holds with double decompositions. Two compounds, A B and C D, mingled together and kept at a low temperature, may severally remain unchanged: the cross affinities between their components may fail to cause re-distribution. Raise the heat of the mixture, and re-distribution takes place; ending in the formation of the compounds A C and B D.

Another truth having a like implication is that chemical elements which, as they ordinarily exist, contain much motion, have combinations less stable than those of which the elements, as they ordinarily exist, contain little motion. The gaseous form of matter implies a relatively large amount of molecular motion, while the solid form implies a relatively small amount. What are the traits of their respective compounds? Those which the permanent gases form with one another cannot resist high temperatures: most of them are easily decomposed by heat; and at a red heat, even the stronger ones yield up their components. On the other hand, the chemical unions between elements that are solid, except at high temperatures, are very stable. In many,

if not indeed in most, cases, such unions are not destroyed by any heat we can produce.

There is, again, the relation, which appears to have a kindred meaning, between instability and amount of composition. "In general, the molecular heat of a compound increases with the degree of complexity." With increase of complexity there also goes increased facility of decomposition. Whence it follows that molecules which contain much motion in virtue of their complexity are those of which the components are most easily re-distributed. This holds not only of the complexity arising from the union of several unlike elements; it holds also of the complexity arising from the union of the same elements in higher multiples. Matter has two solid states, distinguished as crystalloid and colloid; of which the first is due to union of the individual atoms or molecules, and the second to the union of groups of such individual atoms or molecules; and of which the first is stable and the second unstable.

But the most conclusive illustration is furnished by the combinations into which nitrogen enters. These are specially unstable and contain specially great quantities of motion. A peculiarity of nitrogen is that, instead of giving out heat when it combines with other elements, it absorbs heat. Besides carrying with it into the liquid or solid compound it forms the motion which previously constituted it a gas, it takes up additional motion; and where the other element with which it unites is gaseous, the molecular motion proper to this, also, is locked up in the compound. Now these nitrogen compounds are unusually prone to decomposition; and the decompositions of many of them take place with extreme violence. All our explosive substances are nitrogenous—the most destructive of them all, chloride of nitrogen, being one which contains the immense quantity of motion proper to its component gases, plus a further quantity of motion.

Evidently these general chemical truths are parts of the more general physical truth we are tracing out. We see in them that what holds of sensible masses holds also of the insensible masses we call molecules. Like the aggregates formed of them, these ultimate aggregates become more or less integrated according as they lose or gain motion; and like them also, according as they contain much or little motion, they are more or less liable to

undergo secondary re-distributions along with the primary re-distribution.

§ 102. And now having brought this general principle clearly into view, let us observe how, in conformity with it, Evolution becomes, according to the conditions, either simple or compound.

If a little sal-ammoniac or other volatile solid be heated, it is disintegrated by the absorbed molecular motion and rises in gas. If this gas comes in contact with a cold surface, and loses its excess of molecular motion, integration takes place — the substance assumes the form of crystals. This is a case of simple evolution. The concentration of matter and dissipation of motion do not here proceed gradually—do not pass through stages; but the molecular motion which caused assumption of the gaseous state being dissipated, the matter passes suddenly to a solid state. The result is that along with this primary re-distribution there go on no appreciable secondary re-distributions. Substantially the same thing holds with crystals deposited from solutions. Loss of that molecular motion which, down to a certain point, keeps the molecules from uniting, and sudden solidification when the loss goes below that point, occur here as before; and here as before, the absence of a period during which the molecules are partially free and gradually losing their freedom, is accompanied by the absence of minor re-arrangements.

Mark, conversely, what happens when the concentration is slow. A gaseous mass losing its heat and undergoing a consequent decrease of bulk, undergoes also many simultaneous changes. The great quantity of molecular motion contained in it, giving great molecular freedom, renders every part sensitive to every incident force; and, as a result, its parts have various motions besides that implied by their progressing integration. Indeed these secondary motions which we know as currents, are so conspicuous as quite to subordinate the primary motion. Suppose that, presently, the loss of molecular motion has reached the point at which the gaseous state can no longer be maintained, and condensation follows. Under their more closely-united form, the parts of the aggregate display, to a considerable degree, the same phenomena as before. The molecular motion and accompanying molecular

mobility implied by the liquid state, permit easy re-arrangement; and hence there go on rapid and marked changes in the relative positions of parts—local streams produced by slight disturbing forces. But now, if instead of a mobile liquid we take a sluggish one such as molten pitch or asphalte, what happens as the molecular motion decreases? The liquid thickens—its parts cease to be movable among one another with ease; and the transpositions caused by feeble incident forces become slow. Little by little the currents are stopped, but the mass still continues modifiable by stronger incident forces. Gravitation makes it bend or spread out when not supported on all sides, and it may easily be indented. As it cools, it continues to grow stiffer; and eventually, further loss of heat renders it quite hard: its parts are no longer appreciably re-arrangeable by any save violent actions.

Among inorganic aggregates, then, secondary re-distributions accompany the primary re-distribution where this is gradual. During the gaseous and liquid stages, the secondary re-distributions, rapid and extensive as they are, leave no traces: the molecular mobility being such as to negative the fixed arrangement of parts we call structure. On approaching solidity we arrive at a plastic condition in which re-distributions can still be made, though much less easily; and in which they have a certain persistence—a persistence which can, however, become decided only where solidification stops further re-distribution.

Here we see what are the conditions under which Evolution becomes compound, while we see how the compounding of it can be carried far only in cases more special than any hitherto contemplated; since, on the one hand, extensive secondary re-distributions are possible only where there is a great quantity of contained motion, and, on the other hand, such re-distributions can have permanence only where the contained motion has become small: opposing conditions which seem to negative any large amount of permanent secondary re-distribution.

§ 103. And now we are in a position to see how these apparently contradictory conditions are reconciled. We shall appreciate the peculiarity of the aggregates classed as organic, in which Evolution becomes so high; and shall see that this peculiarity consists in the

combination of matter into forms embodying enormous amounts of motion at the same time that they have a great degree of concentration.

For notwithstanding its semi-solid consistence, organic matter contains molecular motion locked up in each of the ways above contemplated separately. Let us note its distinctive traits. Three out of its four chief components are gaseous; and in their uncombined states these gases united in it have so much molecular motion that they are condensible only with extreme difficulty. Hence it is to be inferred that the proteid molecule concentrates an immense amount of motion in a small space. And since many equivalents of these gaseous elements unite in one of these proteid molecules, there must be in it a large quantity of relative motion in addition to that which the ultimate atoms possess. Moreover, organic matter has the peculiarity that its molecules are aggregated into the colloid and not into the crystalloid arrangement; forming, as is supposed, clusters of clusters which have movements in relation to one another. Here, then, is a further mode in which molecular motion is included. Yet again, these compounds, of which the essential parts of organisms are built, are nitrogenous; and we have lately seen it to be a peculiarity of nitrogenous compounds that, instead of giving out heat during their formation, they absorb heat. To all the molecular motion possessed by gaseous nitrogen, is added more motion; and the whole is concentrated in semi-solid protein. Organic aggregates are very generally distinguished, too, by having much insensible motion in a free state—the motion we call heat. Though in many cases the quantity of this contained insensible motion is inconsiderable, in other cases a temperature much above that of the environment is constantly maintained. Once more, there is the vast quantity of motion embodied in the water that permeates organic matter. It is this which, giving to the water its high molecular mobility, gives mobility to the organic molecules partially suspended in it; and preserves that plastic state which so greatly facilitates re-distribution.

These several statements yield no adequate idea of the extent to which living organic substance is thus distinguished from other substances having like sensible forms of aggregation. But some approximation to such an idea may be obtained by contrasting the

bulk occupied by this substance, with the bulk which its constituents would occupy if uncombined. An accurate comparison cannot be made in the present state of science. What expansion would occur if the constituents of the nitrogenous compounds could be divorced without adding motion from without is too complex a question to be answered. But respecting the constituents of that which forms four-fifths of the weight of an ordinary animal—its water—a tolerably definite answer can be given. Were the oxygen and hydrogen of water to lose their affinities, and were no molecular motion supplied to them beyond that contained in water at blood-heat, they would assume a volume twenty times that of the water.* Whether protein under like conditions would expand in a greater or a less degree, must remain an open question; but remembering the gaseous nature of three out of its four chief components, remembering the above-named peculiarity of nitrogenous compounds, remembering the high multiples and the colloidal form, we may conclude that the expansion would be great. We shall not be wrong, therefore, in saying that the elements of the human body, if suddenly disengaged from one another, would occupy far more than a score times the space they do: the movements of their molecules would compel this wide diffusion. Thus the essential characteristic of living organic matter, is that it unites this large quantity of contained motion with a degree of cohesion which permits temporary fixity of arrangement.

§ 104. Besides seeing that organic aggregates differ from other aggregates, alike in the quantity of motion they contain and the amount of re-arrangement of parts which accompanies their progressive integration; we shall see that among organic aggregates themselves, differences in the quantities of contained motion are accompanied by differences in the amounts of re-distribution.

The contrasts among organisms in chemical composition yield us the first illustration. Animals are distinguished from plants by their far greater amounts of structure, as well as by the far greater rapidity with which changes go on in them; and, in

* I am indebted for this result to Dr. [afterwards Sir] Edward Frankland, who has been good enough to have the calculation made for me.

comparison with plants, animals contain immensely larger proportions of those nitrogenous molecules in which so much motion is locked up. So, too, is it with the contrasts between the different parts of each animal. Though certain nitrogenous parts, as cartilage, are stable and inert, yet the parts in which secondary re-distributions have gone on, and are ever going on, most actively, are those mainly formed of highly-compounded nitrogenous molecules; while parts which, like deposits of fat, consist of relatively-simple molecules, that are non-nitrogenous, are seats of but little structure and but little change.

We find proof, too, that the continuance of the secondary re-distributions by which organic aggregates are distinguished, depends on the presence of that locked-up motion which gives mobility to the water diffused through them; and that, other things equal, there is a direct relation between the amount of re-distribution and the amount of contained water. The evidences may be put in three groups. There is the familiar fact that a plant has its formative changes arrested by cutting off the supply of water: the primary re-distribution continues—it withers and shrinks or becomes more integrated—but the secondary re-distributions cease. There is the less familiar fact that the like result occurs in animals—occurs, indeed, after a relatively smaller diminution of water. Certain of the lower animals furnish additional proofs. The *Rotifera* may be rendered apparently lifeless by desiccation, and will yet revive if wetted. When the African rivers it inhabits are dried up, the *Lepidosiren* remains torpid in the hardened mud until return of the rainy season brings water. Humboldt states that during the summer drought, the alligators of the Pampas lie buried in a state of suspended animation beneath the parched surface, and struggle up out of the earth as soon as it becomes humid. The history of each organism teaches the same thing. The young plant, just putting its head above the soil, is more succulent than the adult plant; and the amount of transformation going on in it is relatively greater. In that portion of an egg which displays the formative processes during the early stages of incubation, the changes of arrangement are more rapid than those which an equal portion of the body of a hatched chick undergoes. As may be inferred

from their respective powers to acquire habits and aptitudes, the structural modifiability of a child is greater than that of an adult; and the structural modifiability of a young man is greater than that of an old man: contrasts which are associated with contrasts in the densities of the tissues; since the ratio of water to solid matter diminishes with advancing age. And then we have this relation repeated in the contrasts between parts of the same organism. In a tree, structural changes go on rapidly at the ends of shoots, where the ratio of water to solid matter is very great; while the changes are very slow in the dense and almost dry substance of the trunk. Similarly in animals, we have the contrast between the high rate of change going on in a soft tissue like the brain, and the low rate of change going on in dry non-vascular tissues—hairs, nails, horns, &c.

Other groups of facts prove that the quantity of secondary re-distribution in an organism varies, *cœteris paribus*, according to the contained quantity of the motion called heat. The contrasts between different organisms, and different states of the same organism, unite in showing this. Speaking generally, the amounts of structure and rates of structural change, are smaller throughout the vegetal kingdom than throughout the animal kingdom; and, speaking generally, the heat of plants is less than the heat of animals. Comparisons of the several divisions of the animal kingdom with one another disclose parallel relations. Regarded as a whole, vertebrates are higher in temperature than invertebrates; and they are as a whole higher in activity and complexity. Between subdivisions of the *Vertebrata* themselves, like differences in the degrees of molecular vibration accompany like differences in the degrees of evolution. The least compounded of the *Vertebrata* are the fishes; and, usually, the heat of fishes is nearly the same as that of the water in which they swim: only some large ones being decidedly warmer. Though we habitually speak of reptiles as cold-blooded, and though they have not much more power than fishes of maintaining a temperature above that of their medium, yet since their medium (which is, in the majority of cases, the air of warm climates) is on the average warmer than the medium inhabited by fishes, the temperature of the class reptiles is higher than that of the class fishes; and we see in them

a correspondingly higher complexity. The much more active molecular agitation in mammals and birds, goes along with a considerably greater multiformity of structure and a far greater vivacity. The most instructive contrasts, however, are those occurring in the same organic aggregates at different temperatures. Structural changes in plants vary in rate as the temperature varies. Though light effects those molecular changes causing vegetal growth, yet in the absence of heat, such changes are not effected: in winter there is enough light, but not enough heat. That this is the sole cause of the suspension of growth, is proved by the fact that at the same season, plants contained in hot-houses go on producing leaves and flowers. We see, too, that their seeds, to which light is not simply needless but detrimental, germinate only when the return of a warm season raises the rate of molecular agitation. In like manner the ova of animals, undergoing those changes which produce structure in them, must be kept more or less warm: in the absence of a certain amount of motion among their molecules, the re-arrangement of parts does not go on. Hybernating animals also supply proof that loss of heat carried far retards extremely the vital transformations. In animals which do not hybernate, as in man, prolonged exposure to intense cold causes extreme sleepiness, which implies a lowered rate of organic changes; and if the loss of heat continues, there comes death, or stoppage of these changes.

Here, then, is an accumulation of proofs. Living aggregates are distinguished by the associated facts, that during integration they undergo remarkable secondary changes which other aggregates do not undergo to anything like the same extent; and that they contain (bulks being supposed equal) immensely greater quantities of motion, locked up in various ways.

§ 105. The last chapter closed with the remark that while Evolution is always an integration of Matter and dissipation of Motion, it is in most cases much more. And this chapter opened by specifying the conditions under which Evolution is integrative only, or remains simple, and the conditions under which it is something further than integrative, or becomes compound. In illustrating this contrast between simple and compound Evolution,

and in explaining how the contrast arises, a vague idea of Evolution in general has been conveyed. Unavoidably, we have to some extent forestalled the full discussion of Evolution about to be commenced.

There is nothing in this to regret. A preliminary conception, indefinite but comprehensive, is needful as an introduction to a definite conception. A complex idea is not communicable directly, by giving one after another its component parts in their finished forms; since if no outline pre-exists in the mind of the recipient, these component parts will not be rightly combined. Much labour has to be gone through which would have been saved had a general notion, however cloudy, been conveyed before the distinct and detailed delineation was commenced.

That which the reader has incidentally gathered respecting the nature of Evolution from the foregoing sections, he may thus advantageously use as a rude sketch. He will bear in mind that the total history of every sensible existence is included in its Evolution and Dissolution; which last process we leave for the present out of consideration. He will not forget that whatever aspect of it we are for the moment considering, Evolution is always to be regarded as an integration of Matter and dissipation of Motion, which may be, and usually is, accompanied by other transformations of Matter and Motion. And he will everywhere expect to find that the primary re-distribution ends in forming aggregates which are simple where it is rapid, but which become compound in proportion as its slowness allows the effects of secondary re-distributions to accumulate.

§ 106. There is much difficulty in tracing out transformation so vast, so varied, and so intricate as those now to be entered upon. Besides having to deal with concrete phenomena of all orders, we have to deal with each group of phenomena under several aspects, no one of which can be fully understood apart from the rest and no one of which can be studied simultaneously with the rest. Already we have seen that during Evolution two great classes of changes are going on together; and we shall presently see that the second of these great classes is re-divisible. Entangled with one another as all these changes are, explanation of any one class

or order involves direct or indirect reference to others not yet explained. We can do no more than make the best compromise.

It will be most convenient to devote the next chapter to a detailed account of Evolution under its primary aspect; tacitly recognizing its secondary aspects only so far as the exposition necessitates.

The succeeding two chapters, occupied exclusively with secondary re-distributions, will make no reference to the primary re-distribution beyond that which is unavoidable: each being also limited to one particular trait of the secondary re-distributions.

In a further chapter will be treated a third, and still more distinct, character of the secondary re-distributions.

# CHAPTER XIV

## THE LAW OF EVOLUTION

§ 107. Deduction has now to be verified by induction. Thus far the argument has been that all sensible existences *must*, in some way or other and at some time or other, reach their concrete shapes through processes of concentration; and the facts named have been named merely to clarify the perception of this necessity. But we have not arrived at that unified knowledge constituting Philosophy, until we have seen how existences of all orders *do* exhibit a progressive integration of Matter and accompanying loss of Motion. Tracing, so far as we may by observation and inference, the objects dealt with by the Astronomer and the Geologist, as well as those which Biology, Psychology, and Sociology treat of, we have to consider what direct proof there is that the Cosmos, in general and in detail, conforms to this law.

Throughout the classes of facts successively contemplated, attention will be directed not so much to the truth that every aggregate has undergone, or is undergoing, integration, as to the further truth that in every more or less separate part of every aggregate, integration has been, or is, in progress. Instead of simple wholes and wholes of which the complexity has been ignored, we have now to deal with wholes as they actually exist—mostly made up of many members combined in many ways. And in them we shall have to trace the transformation under several forms—a passage of the total mass from a more diffused to a more consolidated state; a concurrent similar passage in every portion of it that comes to have a distinguishable individuality; and a simultaneous increase of combination among such individualized portions.

§ 108. Our Sidereal System by its general form, by its clusters of stars of various degrees of closeness, and by its nebulæ in all stages of condensation, gives grounds for suspecting that, generally and locally, concentration is going on. Assume that its matter has been, and still is being, drawn together by gravitation, and we have an explanation of its leading traits of structure—from its solidified masses up to its collections of attenuated flocculi barely discernible by the most powerful telescopes, from its double stars up to such complex aggregates as the nubeculæ. Without dwelling on this evidence, however, let us pass to the case of the Solar System.

The belief, so variously supported, that this has had a nebular genesis, is the belief that it has arisen by the integration of matter and concomitant loss of motion. Evolution, under its primary aspect, is illustrated most simply and clearly by this passage of the Solar System from a diffused incoherent state to a consolidated coherent state. While, according to the nebular hypothesis, there has been going on a gradual concentration of the Solar System as an aggregate, there has been a simultaneous concentration of each partially-independent member. The changes of every planet in passing through its stages of nebulous ring, gaseous spheroid, liquid spheroid, and spheroid externally solidified, have in essentials—dissipation of motion and aggregation of matter—paralleled the changes gone through by the general mass; and those of every satellite have done the like. Moreover, at the same time that the matter of the whole, as well as the matter of each partially-independent part, has been thus integrating, there has been the further integration implied by increasing combination among the parts. The satellites of each planet are linked with their primary into a balanced cluster; while the planets and their satellites form with the Sun a compound group, of which the members are more strongly bound together than were the far-spread portions of the nebulous medium out of which they arose.

Even apart from the nebular hypothesis, the Solar System furnishes facts having a like general meaning. Not to make much of the meteoric matter perpetually added to the Earth, and probably to the other planets, as well as, in larger quantities, to the Sun, it will suffice to name two generally-admitted instances.

The one is the retardation of comets by the ethereal medium, and the inferred retardation of planets—a process which must in time, as Lord Kelvin argues, bring comets, and eventually planets, into the Sun. The other is the Sun's still-continued loss of motion in the shape of radiated heat; accompanying the still-continued integration of his mass.

§ 109. To astronomic evolution we pass without break to the evolution which, for convenience, we separate as geologic. The history of the Earth, as traced out from the structure of its crust, carries us back to that molten state which the nebular hypothesis implies; and, as before pointed out (§ 69), the changes called igneous are accompaniments of the advancing consolidation of the Earth's substance and loss of its contained motion. The general effects and the local effects must be briefly exemplified.

Leaving behind the time when the more volatile elements now existing as solids were kept by the high temperature in a gaseous form, we may begin with the fact that until the Earth's surface had cooled far below red heat, the mass of water at present covering three-fifths of it must have existed as vapour. This enormous volume of unintegrated liquid became integrated as fast as dissipation of the Earth's contained motion allowed; leaving, at length, a comparatively small portion uncondensed, which would condense but for the unceasing absorption of molecular motion from the Sun. In the formation of the Earth's crust we have a similar change similarly caused. The passage from a thin solid film, everywhere fissured and movable on the subjacent molten matter, to a crust so thick and strong as to be but now and then very slightly dislocated by disturbing forces, illustrates the process. And while, in this superficial solidification, we see under one form how concentration accompanies loss of contained motion, we see it under another form in that diminution of the Earth's bulk implied by superficial corrugation.

Local or secondary integrations have advanced along with this general integration. A molten spheroid, merely skinned over with solid matter, could have presented nothing beyond small patches of land and water. Differences of elevation, great enough to form islands of considerable size, imply a crust of some rigidity; and

only as the crust grew thick could the land be united into continents divided by oceans. So, too, with the more striking elevations. The collapse of a thin layer round its cooling and contracting contents would throw it into low ridges. The crust must have acquired a relatively great depth and strength before extensive mountain systems of vast elevation became possible: continued integration of it made possible great local integrations. In sedimentary changes a like progress is inferable. Denudation, acting on the small surfaces exposed during early stages, would produce but small local deposits. The collection of detritus into strata of great extent, and the union of such strata into extensive "systems," imply wide surfaces of land and water, as well as subsidences great in both area and depth; so that integrations of this order must have grown more pronounced as the Earth's crust thickened.

§ 110. Already we have recognized the fact that the evolution of an organism is primarily the formation of an aggregate, by the continued incorporation of matter previously spread through a wider space. Every plant grows by taking into itself elements that were before diffused, and every animal grows by re-concentrating these elements previously dispersed in surrounding plants or other animals. Here it will be proper to complete the conception by pointing out that the early history of a plant or animal, still more clearly than its later history, shows us this fundamental process. For the microscopic germ of each organism undergoes, for a long time, no other change than that implied by absorption of nutriment. Cells embedded in the stroma of an ovarium become ova by little else than continued growth at the expense of adjacent materials. And when, after fertilization, a more active evolution commences, its most conspicuous trait is the drawing in, to a germinal centre, of the substance which the ovum contains.

Now, however, our attention must be directed mainly to the secondary integrations which accompany the primary integration. We have to observe how, along with the formation of a larger mass of matter, there goes on a gathering together and consolidation of this matter into parts, as well as a closer combination of the parts. In the mammalian embryo the heart, at first a

long pulsating blood-vessel, by-and-by twists upon itself and integrates. The bile-cells constituting the rudimentary liver, do not simply become different from the wall of the intestine in which they at first lie, but, while accumulating, they diverge from it and consolidate into an organ. The anterior portion of the cerebro-spinal axis, at first continuous with the rest, and not markedly distinguished from it, undergoes a union of its rapidly-growing parts; and at the same time the resulting head folds into a mass marked off from the spine. The like process, variously exhibited in other organs, is meanwhile exhibited by the body as a whole; which becomes integrated somewhat in the same way that an out-spread handkerchief and its contents become integrated when its edges are drawn in and fastened to make a bundle. Kindred changes go on after birth, and continue even up to old age. In man, that solidification of the bony framework which, during child-hood, is seen in the coalescence of portions of the same bone ossified from different centres, is afterwards seen in the coalescence of bones that were originally distinct. The appendages of the vertebræ join with the vertebral centres to which they belong: a change not completed until towards thirty. At the same time the epiphyses, formed separately from the main bodies of their respective bones, have their cartilaginous connexions turned into osseous ones—are fused to the masses beneath them. The component vertebræ of the sacrum, which remain separate till about the sixteenth year, then begin to unite; and in ten or a dozen years more their union is complete. Still later occurs the junction of the coccygeal vertebræ; and there are some other bony unions which remain unfinished unless advanced age is reached. To which add that the increase of density, going on throughout the tissues at large during life, is the formation of a more fully integrated substance.

The species of change thus illustrated, may be traced in all animals. That mode of it which consists in the union of similar parts originally separate, has been described by Milne-Edwards and others, as exhibited in various *Invertebrata;* though it does not seem to have been included by them as an essential trait of organic development. We shall, however, see that local integration is an all-important part of this process, when we find it not only in the successive stages passed through by every embryo, but also in

ascending from the lower creatures to the higher. As manifested in either way, it goes on both longitudinally and transversely; under which different forms we may conveniently consider it. Of *longitudinal integration*, the sub-kingdom *Annulosa* * supplies abundant examples. Its lower members, such as worms and next to them myriapods, are mostly characterized by the great numbers of their segments; reaching in some cases to several hundreds. But in the higher divisions—crustaceans, insects, and arachnids—this number is reduced to twenty-two, thirteen, or even fewer; while, accompanying the reduction, there is a shortening or integration of the whole body, reaching its extreme in the crab and the spider. The significance of these contrasts, as bearing on the doctrine of Evolution, will be clear when it is observed that they are parallel to those which arise during the development of individual annulose animals. The head and thorax of a lobster form one compact box, made by the union of a number of segments which in the embryo were separable. Similarly, the butterfly shows us segments so much more closely united than they were in the caterpillar, as to be, some of them, no longer distinguishable from one another. The *Vertebrata* again, throughout their successively higher classes, furnish like instances of longitudinal union. In most fishes, and in limbless reptiles, none of the vertebræ coalesce. In most mammals and in birds, a variable number of vertebræ become fused to form the sacrum; and in the higher apes and in man, the caudal vertebræ also lose their separate individualities in a single *os coccygis*. That which we may distinguish as *transverse integration*, is well illustrated among the *Annulosa* in the development of the nervous system. Leaving out those most degraded forms which do not present distinct ganglia, we find that the lower annulose animals, in common with the larvæ of the higher, are severally characterized by a double chain of ganglia running from end to end of the body; while in the more perfectly-formed annulose animals, the two chains unite into a single chain. Mr. Newport has described the

* I adhere to this name though of late years the two divisions *Annelida* and *Arthropoda* have usurped its place. Their kinship as lower and higher is admitted, and the name is descriptive of both; for the being formed of rings is their most conspicuous structural trait.

course of this concentration in insects; and by Rathke it has been traced in crustaceans. During the early stages of the common cray-fish, there is a pair of ganglia to each ring. Of the fourteen pairs belonging to the head and thorax, the three pairs in advance of the mouth consolidate to form the cephalic ganglion or brain. Meanwhile, of the remainder, the first six pairs severally unite in the median line, while the rest remain more or less separate. Of these six double ganglia thus formed, the anterior four coalesce into one mass; the remaining two coalesce into another mass, and then these two masses coalesce. Here longitudinal and transverse integration go on simultaneously, and in the highest crustaceans they are both carried still further. The *Vertebrata* exhibit transverse integration in the development of the generative system. The lowest mammals—the *Monotremata*—in common with birds, to which they are in many respects allied, have oviducts which towards their lower extremities are dilated into cavities, each imperfectly performing the function of a uterus. "In the *Marsupialia* there is a closer approximation of the two lateral sets of organs on the median line; for the oviducts converge towards one another and meet (without coalescing) on the median line; so that their uterine dilatations are in contact with each other, forming a true 'double uterus.' . . . As we ascend the series of 'placental' mammals, we find the lateral coalescence becoming more and more complete. . . . In many of the *Rodentia* the uterus still remains completely divided into two lateral halves; whilst in others these coalesce at their lower portions, forming a rudiment of the true 'body' of the uterus in the human subject. This part increases at the expense of the lateral 'cornua' in the higher herbivora and carnivora; but even in the lower quadrumana the uterus is somewhat cleft at its summit." *

Under the head of organic integrations, there remain to be noted another class of illustrations. Whether the *Annulosa* referred to above are or are not originally compound animals, it is unquestionable that there are compound animals among other classes of invertebrates: integration is displayed not within the limits of an individual only but by the union of many individuals. The *Salpidæ* are composite creatures having the shape of chains joined

* Carpenter's *Prin. of Comp. Phys.*, p. 617.

more or less permanently; and *Pyrosoma* shows us a large number united into a cylinder. Moreover in the *Botryllidæ* the merging of the individualities goes so far that instead of having separate skins they are enclosed within a common skin. Among the *Cœlenterata* integration produces half-fused colonies of types unlike these. There are the branched *Hydrozoa* in which many individuals form an aggregate in such a way as to have a common system of nutrition, while some of them undertake special functions; and much the same may be said of those compound *Actinozoa* which are imbedded in the calcareous frameworks we know as corals. And then in certain pelagic types, grouped as *Siphonophora*, the united individuals, in some cases alike, are in other cases severally transformed in adaptation to various functions; so that the component individuals, assuming the characters of different organs, become practically combined into a single organism.

From this kind of integration we pass to a kind in which the individuals are not physically united but simply associated—are integrated only by their mutual dependence. We may set down two kinds—those which occur within the same species, and those which occur between members of different species. More or less of the gregarious tendency is common among animals; and when it is marked, there is, in addition to simple aggregation, some degree of combination. Creatures that hunt in packs, or that have sentinels, or that are governed by leaders, form bodies partially united by co-operation. Among polygamous mammals and birds this mutual dependence is closer; and the social insects show us still more consolidated assemblages: some of them having their members so united that they cannot live independently. How organisms in their totality are mutually dependent, and in that sense integrated, we shall see on remembering—first, that while all animals live directly or indirectly on plants, plants utilize the carbon dioxide excreted by animals; second, that among animals the flesh-eaters cannot exist without the plant-eaters; third, that a large proportion of plants can continue their respective races only by the help of insects. Without detailing the more complex connexions, which Mr. Darwin has so beautifully illustrated, it will suffice to say that the Flora and

Fauna in each habitat, constitute an aggregate so far integrated that many of its species die out if placed amid the plants and animals of another habitat. And this integration, too, increases as organic evolution advances.

§ 111. The phenomena set down in the foregoing paragraph introduce us to others of a higher order, with which they ought, in strictness, to be grouped—phenomena which we may term super-organic. Inorganic bodies present us with certain facts. Additional facts, mostly of a more involved kind, are presented by organic bodies. There remain yet further facts, not presented by any organic body taken singly, but which result from the actions of aggregated organic bodies. Though phenomena of this order are, as we see, foreshadowed among inferior organisms, they become so conspicuous in mankind as socially united, that practically we may consider them to commence here.

In the social organism integrative changes are abundantly exemplified. Uncivilized societies display them when wandering families, such as those of Bushmen, join into tribes of considerable size. A further progress in mass results from the subjugation of weak tribes by strong ones; and in the subordination of their respective chiefs to the conquering chief. Such combinations which, among aboriginal races, are continually being formed and continually broken up, become, among superior races, relatively permanent. If we trace the stages through which our own society, or any adjacent one, has passed, we see this unification from time to time repeated on a larger scale and gaining in stability. The consequent establishment of groups of vassals bound to their respective lords; the subsequent subjection of groups of inferior nobles to dukes or earls; and the still later growth of the kingly power over dukes and earls; are so many instances of increasing consolidation. This process slowly completes itself by destroying the original lines of demarcation. And of the European nations it may be further remarked, that in the tendency to form alliances, in the restraining influences exercised by governments over one another, in the system of settling international arrangements by congresses, as well as in the weakening of commercial barriers and the increasing facilities of communication, we see the beginnings of

a European federation—a still larger integration than any now established.

But it is not only in these external unions of groups with groups, and of the compound groups with one another, that the general law is exemplified. It is exemplified also in unions which take place internally, as the groups become better organized. There are two orders of these, broadly distinguishable as regulative and operative. A civilized society is made unlike a savage tribe by the establishment of regulative classes—governmental, administrative, military, ecclesiastical, legal, &c., which, while they severally have their bonds of union, constituting them sub-classes, are also held together as a general class by a certain community of privileges, of blood, of education, of intercourse. In some societies, fully developed after their particular types, this consolidation into castes, and this union among the upper castes by separation from the lower, eventually grow very decided: to be afterwards rendered less decided, only in cases of social metamorphosis caused by the industrial *régime*. The integrations seen throughout the operative or industrial organization, later in origin, are not merely of this indirect kind, but they are also direct—they show us physical approach. We have integrations consequent on the growths of adjacent parts performing like functions; as, for instance, the junction of Manchester with its calico-weaving suburbs. We have other integrations which arise when, out of several places producing a particular commodity, one gaining more and more of the business, draws to it masters and workers, and leaves the other places to dwindle; as witness the growth of the Yorkshire cloth districts at the expense of those in the West of England; or the absorption by Staffordshire of the pottery manufacture, and the consequent decay of establishments at Derby and elsewhere. We have those more special integrations that arise within the same city; whence result the concentration of corn-merchants about Mark Lane, of civil engineers in Great George Street, of bankers in the centre of the city. Industrial integrations which consist, not in the approximation or fusion of parts, but in the establishment of centres of connexion, are shown in the Bankers' clearing-house and the Railway clearing-house. While of yet another species are those unions which bring into

relation dispersed citizens who are occupied in like ways; as traders are brought by the Exchange, and as are professional men by institutes like those of Civil Engineers, Architects, &c.

These seem to be the last of our instances. Having followed up the general law to social aggregates, there apparently remain no other aggregates to which it can apply. This, however, is not true. Among what were above distinguished as super-organic phenomena, there are sundry further groups of remarkable illustrations. Though evolutions of the various products of social activities cannot be said directly to exemplify the integration of matter and dissipation of motion, yet they exemplify it indirectly. For the progress of Language, of Science, and of the Arts, industrial and æsthetic, is an objective register of subjective changes. Alterations of structure in human beings, and concomitant alterations of structure in aggregates of human beings, jointly produce corresponding alterations of structure in all those things which humanity creates. As in the changed impress on the wax, we read a change in the seal; so in the integrations of advancing Language, Science, and Art, we see reflected certain integrations of advancing human structure, individual and social. A section must be devoted to each group.

§ 112. Among uncivilized races, the many-syllabled names of not uncommon objects, as well as the descriptive character of proper names, show that the words used for the less-familiar things are formed by uniting the words used for the more-familiar things. This process of composition is sometimes found in its incipient stage—a stage in which the component words are temporarily joined to signify some unnamed object, and, from lack of frequent use, do not permanently cohere. But in most inferior languages, the process of "agglutination" has gone far enough to produce some stability in the compound words: there is a manifest integration. How small is this integration, however, in comparison with that reached in well-developed languages, is shown both by the great length of the compound words used for common things and acts, and by the separableness of their elements. Certain North-American tongues illustrate this very well. In a Ricaree vocabulary extending to fifty names of common objects, which in

English are nearly all expressed by single syllables, there is not one monosyllabic word. Things so familiar to these hunting tribes as *dog* and *bow*, are, in the Pawnee language, *ashakish* and *teeragish;* the *hand* and the *eyes* are respectively *iksheeree* and *keereekoo;* for *day* the term is *shakoorooeeshairet*, and for *devil* it is *tsaheekshkakooraiwah;* while the numerals are composed of from two syllables up to five, and in Ricaree up to seven. That the great length of these familiar words implies low development, and that in the formation of higher languages out of lower there is a gradual integration, which reduces the polysyllables to dissyllables and monosyllables, is an inference confirmed by the history of our own language. Anglo-Saxon *steorra* has been in course of time consolidated into English *star*, *mona* into *moon*, and *nama* into *name*. The transition through semi-Saxon is clearly traceable. *Sunu* became in semi-Saxon *sune*, and in English *son:* the final *e* of *sune* being an evanescent form of the original *u*. The change from the Anglo-Saxon plural, formed by the distinct syllable *as*, to our plural formed by the appended consonant *s*, shows the same thing: *smithas* in becoming *smiths*, and *endas* in becoming *ends*, illustrate progressive coalescence. So, too, does the disappearance of the terminal *an* in the infinitive mood of verbs; as shown in the transition from the Anglo-Saxon *cuman* to the semi-Saxon *cumme*, and to the English *come*. Moreover the process has been slowly going on, even since what we distinguish as English was formed. In Elizabeth's time, verbs were still frequently pluralized by the addition of *en*—*we tell* was *we tellen;* and in some places this form of speech may even now be heard. In like manner the terminal *ed* of the past tense, has united with the word it modifies. *Burn-ed* has in pronunciation become *burnt;* and even in writing, the terminal *t* has in some cases taken the place of the *ed*. Only where antique forms in general are adhered to, as in the church service, is the distinctness of this inflection still maintained. Further, we see that the compound vowels have been in many cases fused into single vowels. That in *bread* the *e* and *a* were originally both sounded, is proved by the fact that they are still so sounded in parts where old habits linger. We, however, have contracted the pronunciation into *bred;* and we have made like changes in many other

common words. Lastly, let it be noted that where the repetition is greatest, the process is carried furthest; as instance the contraction of *lord* (originally *hlaford*) into *lud* in the mouths of barristers; and, still better, the coalescence of *God be with you* into *Good bye.*

Besides thus exhibiting the integrative process, Language equally exhibits it throughout all grammatical development. The lowest kinds of human speech, having merely nouns and verbs without inflections, permit no such close union of the elements of a proposition as results when their relations are marked either by inflections or by connective words. Such speech is what we significantly call "incoherent." To a considerable extent, incoherence is seen in the Chinese language. "If, instead of saying *I go* to *London*, *figs come* from *Turkey*, *the sun shines* through *the air*, we said, *I go* end *London*, *figs come* origin *Turkey*, *the sun shines* passage *air*, we should discourse after the manner of the Chinese." From this "aptotic" form, there is a transition, by coalescence, to a form in which the connexions of words are expressed by joining with them certain inflectional words. "In Languages like the Chinese," remarks Dr. Latham, "the separate words most in use to express relation may become adjuncts or annexes." To this he adds the fact that "the numerous inflexional languages fall into two classes. In one, the inflexions have no appearance of having been separate words. In the other, their origin as separate words is demonstrable." From which the inference drawn is, that the "aptotic" languages, by the more and more constant use of adjuncts, gave rise to the "agglutinate" languages, or those in which the original separateness of the inflexional parts can be traced; and that out of these, by further use, arose the "amalgamate" languages, or those in which the original separateness of the inflexional parts can no longer be traced. Strongly corroborative of this inference is the fact that, by such a process, there have grown out of the amalgamate languages, the "anaptotic" languages, of which our own is the best example—languages in which, by further consolidation, inflexions have almost disappeared, while, to express the verbal relations, new kinds of words have been developed. When we see the Anglo-Saxon inflexions gradually lost by contraction during the development

of English, and, though to a less degree, the Latin inflexions dwindling away during the development of French, we cannot deny that grammatical structure is modified by integration; and seeing how clearly the earlier stages of grammatical structure are explained by it, we must conclude that it has been going on from the first.

In proportion to the degree of this integration is the extent to which integration of another order is carried. Aptotic languages are, as already pointed out, necessarily incoherent—the elements of a proposition cannot be completely tied into a whole. But as fast as coalescence produces inflected words, it becomes possible to unite them into sentences of which the parts are so mutually dependent that no considerable change can be made without destroying the meaning. Yet a further stage in this process may be noted. After the development of those grammatical forms which make definite statements possible, we do not at first find them used to express anything beyond statements of a simple kind. A single subject with a single predicate, accompanied by but few qualifying terms, are usually all. If we compare, for instance, the Hebrew scriptures with writings of modern times, a marked difference of aggregation among the groups of words is visible. In the number of subordinate propositions which accompany the principal one; in the various complements to subjects and predicates; and in the numerous qualifying clauses—all of them united into one complex whole—many sentences in modern compositions exhibit a degree of integration not to be found in ancient ones.

§ 113. The history of Science presents facts of the same meaning at every step. Indeed the integration of groups of like entities and like relations, constitutes the most conspicuous part of scientific progress. A glance at the classificatory sciences, shows that the confused incoherent aggregations which the vulgar make of natural objects, are gradually rendered complete and compact, and bound up into groups within groups. While, instead of considering all marine creatures as fish, shell-fish, and jelly-fish, Zoology establishes among them subdivisions under the heads *Vertebrata*, *Annulosa*, *Mollusca*, *Cœlenterata*, &c.; and while, in place of the wide and vague assemblage popularly described as "creeping things," it makes the specific classes *Annelida*, *Myriapoda*, *Insecta*,

*Arachnida;* it simultaneously gives to these an increasing consolidation. The several species, genera, and orders of which each consists, are arranged according to their affinities and tied together under common definitions; at the same time that, by extended observation and rigorous criticism, the previously unknown and undetermined forms are integrated with their respective congeners. Nor is the process less clearly displayed in those sciences which have for their subject-matter, not classified objects but classified relations. Under one of its chief aspects, scientific advance is the advance of generalization; and generalizing is uniting into groups all like co-existences and sequences among phenomena. The colligation of many concrete relations into a generalization of the lowest order, exemplifies this process in its simplest form; and it is again exemplified in a more complex form by the colligation of these lowest generalizations into higher ones, and these into still higher ones. Year by year connexions are established among orders of phenomena that appear unallied; and these connexions, multiplying and strengthening, gradually bring the seemingly unallied orders under a common bond. When, for example, Humboldt quotes the observation of the Swiss—"it is going to rain because we hear the murmur of the torrents nearer,"—when he recognizes the kinship between this and an observation of his own, that the cataracts of the Orinoco are heard at a greater distance by night than by day—when he notes the analogy between these facts and the fact that the unusual visibility of remote objects is also an indication of coming rain—and when he points out that the common cause of these variations is the smaller hindrance offered to the passage of both light and sound, by media which are comparatively homogeneous, either in temperature or hygrometric state; he helps in bringing under one generalization certain traits of light and certain traits of sound. Experiments having shown that light and sound conform to like laws of reflection and refraction, the conclusion that they are both produced by undulations—though undulations of unlike kinds—gains probability: there is an incipient integration of two classes of facts between which no connexion was suspected in times past. A still more decided integration has been of late taking place between the once independent sub-sciences of Electricity, Magnetism, and Light.

The process will manifestly be carried much further. Such propositions as those set forth in preceding chapters, on "The Persistence of Force," "The Transformation and Equivalence of Forces," "The Direction of Motion," and "The Rhythm of Motion," unite within single bonds phenomena belonging to all orders of existences. And if there is such a thing as that which we here understand by Philosophy, there must eventually be reached a universal integration.

§ 114. Nor do the industrial and æsthetic Arts fail to supply us with equally conclusive evidence. The progress from small and simple tools, to complex and large machines, is a progress in integration. Among what are classed as the mechanical powers, the advance from the lever to the wheel-and-axle is an advance from a simple agent to an agent made up of several simple ones. On comparing the wheel-and-axle, or any of the mechanical appliances used in early times with those used now, we see that in each of our machines several of the primitive machines are united. A modern apparatus for spinning or weaving, for making stockings or lace, contains not simply a lever, an inclined plane, a screw, a wheel-and-axle, joined together, but several of each—all made into a whole. Again, in early ages, when horse-power and man-power were alone employed, the motive agent was not bound up with the tool moved; but the two have now become in many cases joined together. The fire-box and boiler of a locomotive are combined with the machinery which the steam works. A much more extensive integration is seen in every factory. Here numerous complicated machines are all connected by driving shafts with the same steam-engine—all united with it into one vast apparatus.

Contrast the mural decorations of the Egyptians and Assyrians with modern historical paintings, and there is manifest an advance in unity of composition—in the subordination of the parts to the whole. One of these ancient frescoes is made up of figures which vary but little in conspicuousness: there are no gradations of light and shade. The same trait may be noted in the tapestries of medieval days. Representing perhaps a hunting scene, one of these contains men, horses, dogs, beasts, birds, trees, and flowers, miscellaneously dispersed: the living objects being variously occupied,

and mostly with no apparent consciousness of one another's proximity. But in paintings since produced, faulty as many of them are in this respect, there is always some co-ordination—an arrangement of attitudes, expressions, lights, and colours, such as to combine the parts into a single scene; and the success with which unity of effect is educed from variety of components is a chief test of merit.

In music, progressive integration is displayed in more numerous ways. The simple cadence embracing but a few notes, which in the chants of savages is monotonously repeated, becomes, among civilized races, a long series of different musical phrases combined into one whole; and so complete is the integration that the melody cannot be broken off in the middle, nor shorn of its final note, without giving us a painful sense of incompleteness. When to the air, a bass, a tenor, and an alto are added; and when to the different voice-parts there is joined an accompaniment; we see integrations of another order which grow gradually more elaborate. And the process is carried a stage higher when these complex solos, concerted pieces, choruses, and orchestral effects, are combined into the vast *ensemble* of an oratorio or a musical drama.

Once more the Arts of literary delineation, narrative and dramatic, furnish us with illustrations. The tales of primitive times, like those with which the story-tellers of the East still amuse their listeners, are made up of successive occurrences, mostly unnatural, that have no natural connexions: they are but so many separate adventures put together without necessary sequence. But in a good modern work of imagination, the events are the proper products of the characters living under given conditions, and cannot at will be changed in their order or kind, without injuring or destroying the general effect. Further, the characters themselves, which in early fictions play their respective parts without showing how their minds are modified by one another or by the events, are now presented to us as held together by complex moral relations, and as acting and reacting on one another's natures.

§ 115. Evolution, then, under its primary aspect, is a change from a less coherent form to a more coherent form, consequent on the dissipation of motion and integration of matter. This is the

universal process through which sensible existences, individually and as a whole, pass during the ascending halves of their histories. This proves to be a character displayed in those earliest changes which the visible Universe is supposed to have undergone, and in those latest changes which we trace in societies and the products of social life. And, throughout, the unification proceeds in several ways simultaneously.

Alike during the evolution of the Solar System, of a planet, of an organism, of a nation, there is progressive aggregation. This may be shown by the increasing density of the matter already contained in it; or by the drawing into it of matter that was before separate; or by both. But in any case it implies a loss of relative motion. At the same time, the parts into which the mass has divided severally consolidate in like manner. We see this in that formation of planets and satellites which has gone on along with the progressive concentration of the nebula that originated the Solar System; we see it in that growth of separate organs which advances, *pari passu*, with the growth of each organism; we see it in that rise of special industrial centres and special masses of population, which is associated with the development of each society. Always more or less of local integration accompanies the general integration. And then, beyond the increased closeness of juxtaposition among the components of the whole, and among the components of each part, there is increase of combination, producing mutual dependence of them. Dimly foreshadowed as this mutual dependence is among inorganic existences, both celestial and terrestrial, it becomes distinct among organic and super-organic existences. From the lowest living forms upwards, the degree of development is marked by the degree in which the several parts constitute a co-operative assemblage—are integrated into a group of organs that live for and by one another. The like contrast between undeveloped and developed societies is conspicuous: there is an ever-increasing co-ordination of parts. And the same thing holds true of social products, as, for instance, of Science; which has become highly integrated not only in the sense that each division is made up of dependent propositions, but in the sense that the several divisions cannot carry on their respective investigations without aid from one another.

## CHAPTER XV

### THE LAW OF EVOLUTION *CONTINUED*

§ 116. CHANGES great in their amounts and various in their kinds, which accompany those dealt with in the last chapter, have thus far been ignored; or, if tacitly recognized, have not been avowedly recognized. Integration of each whole has been described as taking place simultaneously with integration of each of the parts into which it divides itself. But how comes the whole to divide itself into parts? This is a transformation more remarkable than the passage of the whole from an incoherent to a coherent state; and a formula which says nothing about it omits more than half the phenomena to be formulated.

This larger half of the phenomena we have now to treat. Here we are concerned with those secondary re-distributions of matter and motion which go on along with the primary re-distribution. We saw that while in very incoherent aggregates, secondary re-distributions produce but evanescent results, in aggregates that reach and maintain a certain medium state, neither very incoherent nor very coherent, results of a relatively persistent kind are produced—structural modifications. And our next inquiry must be—What is the universal expression for these structural modifications?

Already an implied answer has been given by the title—Compound Evolution. Already in distinguishing as simple Evolution that integration of matter and dissipation of motion which is unaccompanied by secondary re-distributions, it has been tacitly asserted that where secondary re-distributions occur complexity arises: the mass, instead of remaining uniform, must have become multiform. The proposition is an identical one. To say that along with the primary re-distribution there go secondary re-

distributions, is to say that along with the change from a diffused to a concentrated state, there goes a change from a homogeneous state to a heterogeneous state. The components of the mass while becoming integrated have also become differentiated.*

This, then, is the second aspect under which we have to study Evolution. In the last chapter we contemplated existences of all orders as displaying progressive integration. In this chapter we have to contemplate them as displaying progressive differentiation.

§ 117. A growing variety of structure throughout our Sidereal System is implied by the contrasts which indicate aggregation throughout it. We have nebulæ that are diffused and irregular, and others that are spiral, annular, spherical. We have groups of stars the members of which are scattered, and groups concentrated in all degrees down to closely-packed globular clusters. We have these groups differing in the numbers of their members, from those containing several thousand stars to those containing but two. Among individual stars there are great contrasts, real as well as apparent, of size; and from their unlike colours, as well as from their unlike spectra, many contrasts among their physical states are inferable. Beyond which heterogeneities in detail there are general heterogeneities. Nebulæ are numerous in some regions of the heavens, while in others there are only stars. Here the celestial spaces are almost void of objects, and there we see dense aggregations, nebular and stellar together.

The matter of our Solar System during its integration has become more multiform. The concentrating gaseous spheroid, dissipating its contained molecular motion, acquiring more marked unlikenesses of density and temperature between interior and exterior, and leaving behind from time to time annular portions

* The terms here used must be understood in relative senses. Since we know of no such thing as absolute diffusion or absolute concentration, the change can never be anything but a change from a more diffused to a less diffused state—from smaller coherence to greater coherence; and, similarly, as no concrete existences present us with absolute simplicity—as nothing is perfectly uniform—as we nowhere find complete homogeneity, the transformation is literally always towards greater complexity, or increased multiformity, or further heterogeneity. This qualification the reader must bear in mind.

of its mass, underwent differentiations which increased in number and degree, until there was evolved the existing organized group of Sun, planets, and satellites. The heterogeneity of this is variously displayed. There are the immense contrasts between the Sun and the planets, in bulk and in weight; as well as the subordinate contrasts of like kind between one planet and another, and between the planets and their satellites. There is the further contrast between the Sun and the planets in respect of temperature; and there are indications that the planets differ from one another in their proper heats, as well as in the heats which they receive from the sun. Bearing in mind that they also differ in the inclinations of their orbits, the inclinations of their axes, in their specific gravities, and in their physical constitutions, we see how decided is the complexity wrought in the Solar System by those secondary re-distributions which have accompanied the primary re-distribution.

§ 118. Passing from illustrations, which, as assuming the nebular hypothesis, must be classed as more or less hypothetical, let us descend to evidence less open to objection.

It is now agreed among geologists that the Earth was once a molten mass. Originally, then, it was comparatively homogeneous in consistence; and, because of the circulation which takes place in heated liquids, must have been comparatively homogeneous in temperature. It must, too, have been surrounded by an atmosphere consisting partly of the elements of air and water, and partly of those various other elements which assume gaseous forms at high temperatures. Cooling by radiation must, after an immense time, have resulted in differentiating the portion most able to part with its heat; namely, the surface. A further cooling, leading to deposition of all solidifiable elements contained in the atmosphere, and then to precipitation of the water, leaving behind the air, must thus have caused a second marked differentiation; and as the condensation commenced on the coolest parts of the surface—namely, about the poles—there must so have resulted the first geographical distinctions.

To these illustrations of growing heterogeneity, inferred from known laws, Geology adds an extensive series that have been inductively established. The Earth's structure has been age after

age further complicated by additions to the strata which form its crust; and it has been age after age made more various by the increasing composition of these strata; the more recent of which, formed from the detritus of the more ancient, are many of them rendered highly complex by the mixtures of materials they contain. This heterogeneity has been vastly augmented by the actions of the Earth's nucleus on its envelope; whence have resulted not only many kinds of igneous rocks, but the tilting up of sedimentary strata at all angles, the formation of faults and metallic veins, the production of endless dislocations and irregularities. Again, geologists teach us that the Earth's surface has been growing more varied in elevation—that the most ancient mountain-systems are the smallest, and the Andes and Himalayas the most modern; while, in all probability, there have been corresponding changes in the bed of the ocean. As a consequence of this ceaseless multiplication of differences, we now find that no considerable portion of the Earth's exposed surface, is like any other portion, either in contour, in geologic structure, or in chemical composition.

There has been simultaneously going on a gradual differentiation of climates. As fast as the Earth cooled and its crust solidified, inequalities of temperature arose between those parts of its surface most exposed to the Sun and those less exposed; and thus in time there came to be the marked contrasts between regions of perpetual ice and snow, regions where winter and summer alternately reign for periods varying according to the latitude, and regions where summer follows summer with scarcely an appreciable variation. Meanwhile, elevations and subsidences, recurring here and there over the Earth's crust, and producing irregular distributions of land and sea, have entailed various modifications of climate beyond those dependent on latitude; while a yet further series of such modifications has been caused by increased differences of height in the surface, which in sundry places have brought arctic, temperate, and tropical climates to within a few miles of one another. The general results are, that every extensive region has its own meteorologic conditions, and that every locality in each region differs more or less from others in those conditions: as also in its structure, its contour, its soil.

Thus between our existing Earth, the phenomena of whose varied crust neither geographers, geologists, mineralogists, nor meteorologists have yet enumerated, and the molten globe out of which it was evolved, the contrast in heterogeneity is striking.

§ 119. The clearest, most numerous, and most varied illustrations of the advance in multiformity that accompanies the advance in integration, are furnished by living bodies. Distinguished as these are by the great quantity of their contained molecular motion, they exhibit in an extreme degree the secondary redistributions which contained motion facilitates. The history of every plant and every animal, while it is a history of increasing bulk, is also a history of simultaneously-increasing differences among the parts. This transformation has several aspects.

The chemical composition which is almost uniform throughout the substance of a germ, vegetal or animal, gradually ceases to be uniform. The several compounds, nitrogenous and non-nitrogenous, which were homogeneously mixed, segregate by degrees, become diversely proportioned in diverse places, and produce new compounds by transformation or modification. In plants the albuminous and amylaceous matters, which form the substance of the embryo, give origin here to a preponderance of chlorophyll and there to a preponderance of cellulose. Over the parts that are becoming leaf-surfaces, certain of the materials are metamorphosed into wax. In this place starch passes into one of its isomeric equivalents, sugar; and in that place into another of its isomeric equivalents, gum. By secondary change some of the cellulose is modified into wood; while some of it is modified into the allied substance which, in large masses, we call cork. And the more numerous compounds thus arising initiate further unlikenesses by mingling in unlike ratios. The yelk, or essential part of an animal-ovum, having components which are at first evenly diffused among one another, chemically transforms itself in like manner. Its protein, its fats, its salts, become dissimilarly proportioned in different localities; and multiplication of isomeric forms leads to further mixtures and combinations that constitute minor distinctions of parts. Here a mass, darkening by accumulation of hematine, presently dissolves into blood. There fatty

and albuminous matters uniting compose nerve-tissue. At this spot the nitrogenous substance takes on the character of cartilage; and at that, calcareous salts, gathering together in the cartilage, lay the foundation of bone. All these chemical differentiations slowly become more marked and more numerous.

Simultaneously arise contrasts of minute structure. Distinct tissues take the place of matter that had previously no recognizable unlikenesses of parts; and each of the tissues first produced undergoes secondary modifications, causing sub-species of tissues. The granular protoplasm of the vegetal germ, equally with that which forms the unfolding point of every shoot, gives origin to cells that are at first alike. Some of these, as they grow, flatten and unite by their edges to form the outer layer. Others lengthen, and at the same time join together in bundles to lay the foundation of woody fibre. Before much elongating, certain of these cells show a breaking-up of the lining deposit, which, during elongation, becomes a spiral thread, or a reticulated framework, or a series of rings; and by the longitudinal union of cells so lined, vessels are formed. Meanwhile each of these differentiated tissues is re-differentiated: instance that constituting the essential part of a leaf, the upper stratum of which is composed of chlorophyll cells remaining closely packed, while the lower stratum becomes spongy. Of the same general character are the transformations undergone by the fertilized ovum, which, at first a cluster of similar cells, quickly reaches a stage marked by dissimilarity of the cells. More frequently recurring fission of the superficial cells, a resulting smaller size of them, and subsequent union of them into an outer layer, constitute the first differentiation; and the middle area of this layer is rendered unlike the rest by still more active processes of like kind. By such modifications upon modifications, many and various, arise the classes and sub-classes of tissues which, intricately combined one with another, compose organs.

Equally conforming to the law are the changes in general shape and in the shapes of organs. All germs are at first spheres and all limbs are at first buds or mere rounded lumps. From this primordial uniformity and simplicity, there take place divergences, both of the wholes and of the leading parts, towards multiformity

of contour and towards complexity of contour. Remove the compactly-folded young leaves that terminate every shoot, and the nucleus is found to be a central knob bearing lateral knobs, one of which may grow into either a leaf, a sepal, a petal, a stamen, or a carpel: all these eventually-unlike parts being at first alike. The shoots themselves also depart from their primitive unity of form; and while each branch becomes more or less different from the rest, the whole exposed part of the plant becomes different from the imbedded part. So, too, is it with the organs of animals. One of the *Arthropoda*, for instance, has limbs that were originally indistinguishable from one another —composed a homogeneous series; but by continuous divergences there have arisen among them unlikenesses of size and form, such as we see in the crab and the lobster. Vertebrate creatures equally exemplify this truth. The wings and legs of a bird are of similar shapes when they bud-out from the sides of the embryo.

Thus in every plant and animal, conspicuous secondary re-distributions accompany the primary re-distribution. A first difference between two parts; in each of these parts other differences which presently become as marked as the first; and a like multiplication of differences in geometrical progression, until there is reached that complex combination constituting the adult. This is the history of all living things whatsoever. Pursuing an idea which Harvey set afloat, it has been shown by Wolff and Von Baer, that during its development each organism passes from a state of homogeneity to a state of heterogeneity. For a generation this truth has been accepted by biologists.*

* It was in 1852 that I became acquainted with Von Baer's expression of this general principle. The universality of law had ever been with me a postulate, carrying with it a correlative belief, tacit if not avowed, in unity of method throughout Nature. This statement that every plant and animal, originally homogeneous, becomes gradually heterogeneous, set up a co-ordination among thoughts which were previously unorganized, or but partially organized. It is true that in *Social Statics* (Part IV., §§ 12–16), published before meeting with Von Baer's formula, the development of an individual organism and the development of a social organism, are described as alike consisting in advance from simplicity to complexity, and from independent like parts to mutually-dependent unlike parts. But though admitting of extension to other super-organic phenomena, this statement was too special to

§ 120. When we pass from individual forms of life to life at large, and ask whether the same law is seen in the *ensemble* of its manifestations—whether modern plants and animals have more heterogeneous structures than ancient ones, and whether the Earth's present Flora and Fauna are more heterogeneous than the Flora and Fauna of the past,—we find the evidence so fragmentary that nearly every conclusion is open to dispute. Three-fifths of the Earth's surface being covered by water; a great part of the exposed land being inaccessible to, or untravelled by, the geologist; the most of the remainder having been scarcely more than glanced at; and even familiar portions, as England, having been so imperfectly explored that a new series of strata has been added within these few years; it is clearly impossible to say with any certainty what creatures have, and what have not, existed at any particular period. Considering the perishable nature of many of the lower organic forms, the metamorphosis of many beds of sediment, and the gaps that occur among the rest, we shall see further reason for distrusting our deductions. On the one hand, the repeated discovery of vertebrate remains in strata previously supposed to contain none—of reptiles where only fish were thought to exist, and of mammals where it was believed there were no creatures higher than reptiles; renders it daily more manifest how small is the value of negative evidence. On the other hand, the worthlessness of the assumption that we have found the earliest, or anything like the earliest, organic remains, is becoming equally clear.

admit of extension to inorganic phenomena. The great aid rendered by Von Baer's formula arose from its higher abstractness; since, only when organic transformations had been expressed in the most abstract terms, was the way opened for seeing what they had in common with inorganic transformations. The conviction that this process of change gone through by each unfolding organism, is a process gone through by all things, found its first coherent statement in an essay on "Progress: its Law and Cause"; which I published in the *Westminster Review* for April, 1857—an essay with the first half of which this chapter coincides in substance, and partly in form. In that essay, however, as also in the first edition of this work, I fell into the error of supposing that the transformation of the homogeneous into the heterogeneous constitutes Evolution. We have seen that this is not so. It constitutes the secondary re-distribution accompanying the primary re-distribution in that Evolution which we distinguish as compound; or rather, as we shall presently see, it constitutes the most conspicuous trait of this secondary re-distribution.

That the oldest known aqueous formations have been greatly changed by igneous action, and that still older ones have been totally transformed by it, is becoming undeniable. And the fact that sedimentary strata earlier than any we know have been melted up, being admitted, it must also be admitted that we cannot say how far back in time this destruction of sedimentary strata has been going on. For aught we know to the contrary, only the last chapters of the Earth's biological history may have come down to us.

Most inferences must thus be extremely questionable. If a progressionist argues that the earliest known vertebrate remains are those of Fishes, which are the most homogeneous of the *Vertebrata;* that Reptiles, which are more heterogeneous, are later; and that later still, and more heterogeneous still, are Mammals and Birds; it may be replied that the Palæozoic deposits, not being estuary deposits, are not likely to contain the remains of terrestrial *Vertebrata*, which may nevertheless have existed. A like answer may be made to the argument that the vertebrate fauna of the Palæozoic period, consisting, so far as we know, entirely of Fishes, was less heterogeneous than the modern vertebrate fauna, which includes Reptiles, Birds and Mammals, of multitudinous genera; while a uniformitarian may contend with great show of truth, that this appearance of higher and more varied forms in later geologic eras, was due to progressive immigration—that a continent slowly upheaved from the ocean at a point remote from pre-existing continents, would necessarily be peopled from them in a succession like that which our strata display. At the same time the counter-arguments may be proved equally inconclusive. When, to show that there cannot have been a continuous evolution of the more homogeneous organic forms into the more heterogeneous ones, the uniformitarian points to the breaks which occur in the succession of these forms, there is the sufficient answer that current geological changes show us why such breaks must occur, and why, by subsidences and elevations of large areas, there must be produced breaks so immense as those which divide the great geologic epochs. Or again, if the opponent of the development hypothesis cites the facts set forth by Professor Huxley in his lecture on "Persistent Types"—if he points out

that "of some two hundred known orders of plants, not one is exclusively fossil," while "among animals, there is not a single totally extinct class; and of the orders, at the outside not more than seven per cent. are unrepresented in the existing creation"—if he urges that among these some have continued from the Silurian epoch to our own day with scarcely any change—and if he infers that there is a much greater average resemblance between the living forms of the past and those of the present than consists with the hypothesis; there is still a satisfactory reply, on which in fact Prof. Huxley insists; namely, that we have evidence of a "pre-geologic era" of unknown duration. And, indeed, when we remember that the enormous subsidences of the Silurian period show the Earth's crust to have been approximately as thick then as it is now—when we conclude that the time taken to form so thick a crust, must have been immense as compared with the time which has since elapsed—when we assume, as we must, that during this comparatively immense time the geologic and biologic changes went on at their usual rates; it becomes manifest, not only that the palæontological records which we find do not negative the theory of evolution, but that they are such as might rationally be looked for.

Moreover, though the evidence suffices neither for proof nor disproof, yet some of its most conspicuous facts support the belief, that the more heterogeneous organisms and groups of organisms, have been evolved from the less heterogeneous ones. The average community of type between the fossils of adjacent strata, and especially the community found between the latest tertiary fossils and creatures now existing, is one of these facts. The discovery in some modern deposits of such forms as the Palæotherium and Anaplotherium, which, according to Prof. Owen, had a type of structure intermediate between some of the types now existing, is another of these facts. And the comparatively recent appearance of Man, is a third fact of this kind, which possesses still greater significance.* Hence we may say that though our knowledge of

* I leave these sentences as they stood when written nearly forty years ago, thinking it better to name in a note the vast amount of confirmatory evidence which has accumulated in the interval, and which renders unassailable the conclusion drawn. In 1862 no one thought it possible that there could be

past life upon the Earth is relatively small, yet what we have, and what we continually add to it, support the belief that there has been an evolution of the simple into the complex alike in individual forms and in the aggregate of forms.

§ 121. Advance from the homogeneous to the heterogeneous is clearly displayed in the progress of the latest and most heterogeneous creature—Man. While the peopling of the Earth has been going on, the human organism has grown more heterogeneous among the civilized divisions of the species; and the species, as a whole, has been made more heterogeneous by the multiplication of races and the differentiation of them from one another. In proof of the first of these statements may be cited the fact that, in the relative development of the limbs, civilized men depart more widely from the general type of the placental mammalia, than do the lowest men. Though often possessing well-developed body and arms, the Papuan has very small legs: thus reminding us of the man-like apes, in which there is no great contrast in size between the hind and fore limbs. But in the European, the greater length and massiveness of the legs has become marked—the fore and hind limbs are relatively more heterogeneous. The greater ratio which the cranial bones bear to the facial bones, illustrates the same truth. Among the *Vertebrata* in general, evolution is marked by an increasing heterogeneity in the vertebral column, and especially in the components of the skull: the higher forms being distinguished by the relatively larger size of the bones which cover the

proof of a transition between reptiles and birds; and yet since that time forms unquestionably transitional have been found. Though the indications of many other such kinships, by the discoveries of intercalary forms, have not yet in most cases been followed by proofs of continuous genealogy, yet it is otherwise in the case of the horse, the ancestry of which has been traced. Evidence of descent from a three-toed animal of the Miocene period is considered by Prof. Huxley as conclusive: sceptical and cautious though he is. In his Inaugural Address to the Geological Society in 1870, on "Paleontology and the Doctrine of Evolution," many further illustrations are given of kinships between ancient and modern types. Nowadays, indeed, there is universal agreement among naturalists (a few surviving disciples of Cuvier in France being excepted) that all organic forms have arisen by the superposing of modifications upon modifications: increase in heterogeneity being an average implication.

brain, and the relatively smaller size of those which form the jaws, &c. Now this trait, which is stronger in Man than in any other creature, is stronger in the European than in the savage. Moreover, from the greater extent and variety of faculty he exhibits, we may infer that the civilized man has also a more complex or heterogeneous nervous system than the uncivilized man; and, indeed, the fact is in part visible in the increased ratio which his cerebrum bears to the subjacent ganglia. If further elucidation be needed, every nursery furnishes it. In the infant European we see sundry resemblances to the lower human races; as in the flatness of the alæ of the nose, the depression of its bridge, the divergence and forward opening of the nostrils, the form of the lips, the absence of a frontal sinus, the width between the eyes, the smallness of the legs. Now as the developmental process by which these traits are turned into those of the adult European, is a continuation of that change from the homogeneous to the heterogeneous displayed during the previous evolution of the embryo; it follows that the parallel developmental process by which the like traits of the barbarous races have been turned into those of the civilized races, has also been a continuation of the change from the homogeneous to the heterogeneous. The truth of the second statement is so obvious as scarcely to need illustration. Every work on Ethnology, by its divisions and subdivisions of races, bears testimony to it. Even were we to admit that Mankind originated from several separate stocks, it would still remain true that as, from each of these stocks, there have sprung many now widely different tribes, which are proved by philological evidence to have had a common origin, the race as a whole is more heterogeneous than it once was. Add to which that we have, in the Anglo-Americans, an example of a new variety arising within these few generations; and that, if we may trust to the descriptions of observers, we are likely soon to have another such in Australia.

§ 122. On passing from Humanity under its individual form to Humanity as socially embodied, we find the general law still more variously exemplified. The change from the homogeneous to the heterogeneous is displayed equally in the progress of civilization as

a whole, and in the progress of every tribe or nation; and it is still going on with increasing rapidity.

Society in its first and lowest stage is a homogeneous assemblage of individuals having like powers and like functions: the only marked difference of function being that which accompanies difference of sex. Every man is warrior, hunter, fisherman, tool-maker, builder; every woman performs the same drudgeries; every family is self-sufficing, and, save for purposes of companionship, aggression, and defence, might as well live apart from the rest. Very early, however, in the course of social evolution, we find an incipient differentiation between the governing and the governed. Some kind of chieftainship soon arises after the advance from the state of separate wandering families to that of a nomadic tribe. The authority of the strongest and cunningest makes itself felt among savages, as in a herd of animals or a posse of schoolboys: especially in war. At first, however, it is indefinite, uncertain; is shared by others of scarcely inferior power; and is unaccompanied by any difference in occupation or style of living: the first ruler kills his own game, makes his own weapons, builds his own hut, and, economically considered, does not differ from others of his tribe. Along with conquests and the massing of tribes, the contrast between the governing and the governed grows more decided. Supreme power becomes hereditary in one family; the head, first military and then political, ceasing to provide for his own wants, is served by others; and he begins to assume the sole office of ruling. At the same time there has been arising a co-ordinate species of government—that of Religion. Ancient records and traditions show that the earliest conquerors and kings came to be regarded as divine personages. The maxims and commands they uttered during their lives were held sacred after their deaths, and were enforced by their divinely-descended successors; who in their turns were promoted to the pantheon of the race, there to be worshipped and propitiated along with their predecessors. For a long time these connate forms of government—civil and religious—remain closely associated. For many generations the king continues to be the chief priest, and the priesthood to be members of the royal race. For many ages religious law continues to contain more or less of civil regulation, and civil

law to possess more or less of religious sanction; and even among the most advanced nations these two controlling agencies are by no means completely differentiated from each other. Having a common root with these, and gradually diverging from them, we find yet another controlling agency—that of Manners or ceremonial usages. Titles of honour were originally the names of the god-king; afterwards of God and the king; still later of persons of high rank; and finally came, some of them, to be used between man and man. Forms of complimentary address were at first expressions of propitiation from prisoners to their conqueror, or from subjects to their ruler, either human or divine—expressions that were afterwards used to propitiate subordinate authorities, and slowly descended into ordinary intercourse. Modes of salutation were once signs of subjection to a victor, afterwards obeisances made before the monarch and used in worship of him when dead. Presently others of the god-descended race were similarly saluted; and by degrees some of the salutations have become the due of all.* Thus, no sooner does the originally homogeneous social mass differentiate into the governed and the governing parts, than this last exhibits an incipient differentiation into religious and secular—Church and State; while at the same time or still earlier there begins to take shape, that less definite species of government which rules our daily intercourse—a species of government which, as we may see in heralds' colleges, in books of the peerage, in masters of ceremonies, is not without a certain embodiment of its own. Each of these kinds of government is itself subject to successive differentiations. In the course of ages, there arises, as among ourselves, a highly complex political organization of monarch, ministers, lords and commons, with their subordinate administrative departments, courts of justice, revenue offices, &c., supplemented in the provinces by municipal governments, county governments, parish or union governments—all of them more or less elaborated. By its side there grows up a highly complex religious organization, with its various grades of officials from archbishops down to sextons, its colleges, convocations, ecclesiastical courts, &c.; to all which must be added the ever-multiplying

* For detailed proof see essay on "Manners and Fashion" in *Essays*, &c., Vol. III.

independent sects, each with its general and local authorities. And simultaneously there is developed a complicated system of customs, manners, and temporary fashions, enforced by society at large, and serving to control those minor transactions between man and man which are not regulated by civil and religious law. Moreover, it is to be observed that this increasing heterogeneity in the governmental appliances of each nation, has been accompanied by an increasing heterogeneity in the governmental appliances of different nations. All peoples are more or less unlike in their political systems and legislation, in their creeds and religious institutions, in their customs and ceremonial usages.

Meanwhile there has been going on a differentiation of a more familiar kind; that, namely, by which the mass of the community has been segregated into distinct classes and orders of workers. While the governing part has undergone the complex development above indicated, the governed part has undergone a more complex development, which has resulted in that minute division of labour characterizing advanced nations. It is needless to trace out this progress from its first stages, up through the caste-divisions of the East and the incorporated guilds of Europe, to the elaborate producing and distributing organization existing among ourselves. Political economists have long since described the industrial progress which, through increasing division of labour, ends with a civilized community whose members severally perform different actions for one another; and they have further pointed out the changes through which the solitary producer of any one commodity, is transformed into a combination of producers who, united under a master, take separate parts in the manufacture of such commodity. But there are yet other and higher phases of this advance from the homogeneous to the heterogeneous in the industrial organization of society. Long after considerable progress has been made in the division of labour among the different classes of workers, there is relatively little division of labour among the widely separated parts of the community: the nation continues comparatively homogeneous in the respect that in each district the same occupations are pursued. But when roads and other means of transit become numerous and good, the different districts begin to assume different functions,

and to become mutually dependent. The calico-manufacture locates itself in this county, the woollen-manufacture in that; silks are produced here, lace there; stockings in one place, shoes in another; pottery, hardware, cutlery, come to have their special towns; and ultimately every locality grows more or less distinguished from the rest by the leading occupation carried on in it. Nay, more, this subdivision of functions shows itself not only among the different parts of the same nation, but among different nations. That exchange of commodities which free-trade promises so greatly to increase will ultimately have the effect of specializing, in a greater or less degree, the industry of each people. So that beginning with a primitive tribe, almost if not quite homogeneous in the functions of its members, the progress has been, and still is, towards an economic aggregation of the whole human race; growing ever more heterogeneous in respect of the separate functions assumed by separate nations, the separate functions assumed by the local sections of each nation, the separate functions assumed by the many kinds of producers in each place, and the separate functions assumed by the workers united in growing or making each commodity. And then, lastly, has to be named the vast organization of distributers, wholesale and retail, forming so conspicuous an element in our town-populations, which is becoming ever more specialized in its structure.

§ 123. Not only is the law thus exemplified in the evolution of the social organism, but it is exemplified in the evolution of all products of human thought and action, whether concrete or abstract, real or ideal. Let us take Language as our first illustration.

The lowest form of language is the exclamation, by which an entire idea is vaguely conveyed through a single sound; as among the lower animals. That human language ever consisted solely of exclamations, and so was strictly homogeneous in respect of its parts of speech, we have no evidence. But that language can be traced down to a form in which nouns and verbs are its only elements, is an established fact. In the gradual multiplication of parts of speech out of these primary ones—in the differentiation of verbs into active and passive, of nouns into abstract and concrete—

in the rise of distinctions of mood, tense, person, of number and case—in the formation of auxiliary verbs, of adjectives, adverbs, pronouns, prepositions, articles—in the divergence of those orders, genera, species, and varieties of parts of speech by which civilized races express minute modifications of meaning; we see a change from the homogeneous to the heterogeneous. And it may be remarked that it is more especially because it has carried this subdivision of functions further than any other language, that the English language is structurally superior. Another process throughout which we may trace the development of language, is the differentiation of words of allied meanings. Philology early disclosed the truth that in all languages words may be grouped into families having each a common ancestry. An aboriginal name, applied indiscriminately to each member of an extensive and ill-defined class of things or actions, presently undergoes modifications by which the chief divisions of the class are expressed. These several names, springing from the primitive root, themselves become the parents of other names still furthur modified. And by the aid of those systematic modes, which presently arise, of making derivatives and forming compounds expressing still smaller distinctions, there is finally developed a tribe of words so heterogeneous in sound and meaning, that to the uninitiated it seems incredible they should have had a common origin. Meanwhile, from other roots there are being evolved other such tribes, until there results a language of a hundred thousand different words, signifying as many different objects, qualities, acts. Yet another way in which language advances from the homogeneous to the heterogeneous, is by the multiplication of languages. Whether, as Max Müller and Bunsen think, all languages have grown from one stock, or whether, as some philologists say, they have grown from two or more stocks, it is clear that since large families of languages, as the Indo-European, are of one parentage, there have arisen multiplied kinds through a process of continuous divergence. The diffusion over the Earth's surface which has led to differentiation of the race, has simultaneously led to differentiation of its speech: a truth which we see further illustrated in each country by the dialects found in separate districts. Thus linguistic changes conform to the general law, alike in the evolution of languages, in the

evolution of families of words, and in the evolution of parts of speech. If in our conception of language we include not its component words only but those combinations of them by which distinct ideas are conveyed—namely sentences—we have to recognize one more aspect of its progress from homogeneity to heterogeneity which has accompanied the progress in integration. Rude speech consists of simple propositions having subjects and predicates indefinitely linked; and anything like a complex meaning is conveyed by a succession of such propositions connected only by juxtaposition. Even in the speech of comparatively developed peoples, as the Hebrews, we find very little complexity. Compare a number of verses from the Bible with some paragraphs from a modern writer, and the increase in heterogeneity of structure is very conspicuous. And beyond the fact that many of our ordinary sentences are by the supplementary clauses, secondary propositions, and qualifying phrases they contain made relatively involved, there is the fact that there is great variety among the sentences in a page: now long, now short, now formed in one way, now in another, so that a double progress in heterogeneity in the style of composition is displayed.

On passing from spoken to written language, we come upon several classes of facts, having similar implications. Written language is connate with Painting and Sculpture; and at first all three are appendages of Architecture, and have a direct connexion with the early form of settled government—the theocratic. Merely noting the fact that sundry wild races, as the Australians and the tribes of South Africa, are given to depicting personages and events on the walls of caves, which are probably regarded as sacred places, let us pass to the case of the Egyptians. Among them, as also among the Assyrians, we see mural paintings used to decorate the temple of the god and the palace of the king (which were, indeed, originally identical); and as such they were governmental appliances in the same sense that state pageants and religious feasts were. Further, they were governmental appliances in virtue of representing the worship of the god, the triumphs of the god-king, the submission of his subjects, and the punishment of the rebellious. And yet again they were governmental, as being the products of an art reverenced by the people as a sacred mystery. From the

constant use of this pictorial representation, there grew up the but slightly-modified practice of picture writing—a practice which was found still extant among the Mexicans at the time they were discovered. By abbreviations analogous to those still going on in our own language, the most familiar of these pictured figures were successively simplified; and ultimately there grew up symbols, most of which had but distant resemblances to the things for which they stood. The inference that the hieroglyphics of the Egyptians thus arose, is confirmed by the fact that the picture writing of the Mexicans was found to have given birth to a like family of ideographic forms; and among them, as among the Egyptians, these had been partially differentiated into the *kuriological* or imitative, and the *tropical* or symbolic: which were, however, used together in the same record. In Egypt, written language underwent a further differentiation, resulting in the *hieratic* and the *epistolographic* or *enchorial:* both derived from the original hieroglyphic. At the same time for proper names, which could not be otherwise expressed, phonetic symbols were employed; and though the Egyptians never achieved complete alphabetic writing, yet it can scarcely be doubted that among other peoples phonetic symbols, occasionally used in aid of ideographic ones, were the germs out of which alphabetic writing arose. Once having become separate from hieroglyphics, alphabetic writing itself underwent numerous differentiations—multiplied alphabets were produced: between most of which, however, connexions can still be traced. And in each civilized nation there have now grown up, for the representation of one set of sounds, several sets of written signs, used for distinct purposes. Finally, through a yet more important differentiation, came printing; which, uniform in kind as it was at first, has since become multiform.

§ 124. While written language was passing through its earlier stages of development, the mural decoration which formed its root was being differentiated into Painting and Sculpture. The gods, kings, men, and animals represented, were originally marked by indented outlines and coloured. In most cases these outlines were of such depth, and the object they circumscribed so far rounded, as to form a species of work intermediate between

intaglio and bas-relief. In other cases we see an advance upon this: the spaces between the figures being chiselled out, and the figures themselves appropriately tinted, a painted bas-relief was produced. The restored Assyrian architecture at Sydenham exhibits this style of art carried to greater perfection: the persons and things represented, though still barbarously coloured, are carved with more truth and in greater detail; and in the winged lions and bulls used for the angles of gateways, we see advance towards a completely sculptured figure; which, nevertheless, is still coloured and still forms part of the building. But though in Assyria the production of a statue proper seems to have been little, if at all, attempted, we may trace in Egyptian art the gradual separation of the sculptured figure from the wall. While a walk through the collection in the British Museum will afford an opportunity of observing transitions, it will bring into view much evidence that the independent statues were derived from bas-reliefs: nearly all of them not only display that lateral attachment of the arms with the body which is a characteristic of bas-relief, but have the back of the statue united from head to foot with a block which stands in place of the original wall. Greece repeated the leading stages of this progress. As in Egypt and Assyria, these twin arts were at first united with each other and with their parent, Architecture; and were aids of Religion and Government. On the friezes of Greek temples, we see coloured bas-reliefs representing sacrifices, battles, processions, games—all in some sort religious. On the pediments we see painted sculptures partially united with the tympanum, and having for subjects the triumphs of gods or heroes. Even when we come to statues that are definitely separated from the buildings to which they pertain, we still find them coloured; and only in the later periods of Greek civilization, does the differentiation of painting from sculpture appear to have become complete. In Christian art there occurred a parallel re-genesis. All early paintings and sculptures throughout Europe were religious in subject—represented Christs, crucifixions, virgins, holy families, apostles, saints. They formed integral parts of church architecture, and were among the means of exciting worship: as in Roman Catholic countries they still are. Moreover, the early sculptures

of Christ on the cross, of virgins, of saints, were coloured; and it needs but to call to mind the painted madonnas and crucifixes still abundant in continental churches, to perceive the significant fact that painting and sculpture continue in closest connexion with each other, where they continue in closest connexion with their parent. Even when Christian sculpture became separate from painting, it was still at first religious and governmental in its subjects—was used for tombs in churches and statues of saints and kings; while, at the same time, painting, where not purely ecclesiastical, was applied to the decoration of palaces, and after representing royal personages, was almost wholly devoted to sacred legends. Only in modern times have painting and sculpture become entirely secular arts. Only within these few centuries has painting been divided into historical, landscape, marine, architectural, animal, still-life, &c., and sculpture grown heterogeneous in respect of the variety of real and ideal subjects with which it occupies itself.

Strange as it seems then, all forms of written language, of painting, of sculpture, have a common root in those rude drawings on skins and cavern-walls by which savages commemorated notable deeds of their chiefs, and which, during social progress, developed into the politico-religious decorations of ancient temples and palaces. Little resemblance as they now have, the bust that stands on the console, the landscape that hangs against the wall, and the copy of the *Times* lying upon the table, are remotely akin. The brazen face of the knocker which the postman has just lifted, is related not only to the woodcuts of the *Illustrated London News* which he is delivering, but to the characters of the *billet-doux* which accompanies it. Between the painted window, the prayer-book on which its light falls, and the adjacent monument, there is consanguinity. The effigies on our coins, the signs over shops, the figures that fill every ledger, the coat-of-arms outside the carriage-panel, and the placards inside the omnibus, are, in common with dolls, blue-books and paper-hangings, lineally descended from the sculpture-paintings and picture-writings in which the Egyptians represented and recorded the triumphs and worship of their god-kings. Perhaps no example can be given which more vividly illustrates the multiplicity and

heterogeneity of the products that in course of time may arise by successive differentiations from a common stock.

The transformation of the homogeneous into the heterogeneous thus displayed in the separation of Painting and Sculpture from Architecture and from each other, and in the greater variety of subjects they embody, is further displayed in the structure of each work. A modern picture or statue is of far more complex nature than an ancient one. An Egyptian sculpture-fresco represents all its figures as on one plane—that is, at the same distance from the eye; and so is less heterogeneous than a painting that represents them as at various distances. It exhibits all objects as similarly lighted; and so is less heterogeneous than a painting which exhibits different objects, and different parts of each object, as in different degrees of light. It uses scarcely any but the primary colours, and these in their full intensities; and so is less heterogeneous than a painting which, introducing the primary colours but sparingly, employs an endless variety of intermediate tints, each of heterogeneous composition, and differing from the rest not only in quality but in strength. Moreover, these earliest works manifest great uniformity of conception. In ancient societies the modes of representation were so fixed that it was sacrilege to introduce a novelty. In Egyptian and Assyrian bas-reliefs, deities, kings, priests, attendants, winged figures and animals, are in all cases depicted in like positions, special to each class, holding like implements, doing like things, and with like expression or non-expression of face. If a palm-grove is introduced, all the trees are of the same height, have the same number of leaves, and are equidistant. When water is imitated, each wave is a counterpart of the rest; and the fish, almost always of one kind, are evenly distributed. The beards of the Assyrian kings, gods, and winged figures, are everywhere similar; as are the manes of the lions, and equally so those of the horses. Hair is represented throughout by one form of curl. The king's beard is built up of compound tiers of uniform curls, alternating with twisted tiers placed transversely, and arranged with perfect regularity; and the terminal tufts of the bulls' tails are represented in exactly the same manner. Without tracing out analogous traits in early Christian art, in which, though less

striking, they are still visible, the advance in heterogeneity will be sufficiently manifest on remembering that in the pictures of our own day the composition is endlessly varied; the attitudes, faces, expressions, unlike; the subordinate objects different in size, form, position, texture. Or, if we compare an Egyptian statue, seated upright on a block, with hands on knees, fingers outspread and parallel, eyes looking straight forward, and the two sides perfectly symmetrical, with a statute of the advanced Greek or the modern school, which is asymmetrical in respect of the position of the head, the body, the limbs, the arrangement of the hair, dress, appendages, and in its relations to neighbouring objects, we see the change from the homogeneous to the heterogeneous clearly manifested.

§ 125. In the co-ordinate origin and gradual differentiation of Poetry, Music, and Dancing, we have another series of illustrations. Rhythm in speech, rhythm in sound, and rhythm in motion, were in the beginning, parts of the same thing. Among existing barbarous tribes we find them still united. The dances of savages are accompanied by some kind of monotonous chant, the clapping of hands, the striking of rude instruments: there are measured movements, measured words, and measured tones; and the whole ceremony, usually having reference to war or sacrifice, is of governmental character. The early records of the historic races similarly show these three forms of metrical action united in religious festivals. In the Hebrew writings we read that the triumphal ode composed by Moses on the defeat of the Egyptians, was sung to an accompaniment of dancing and timbrels. The Israelites danced and sung "at the inauguration of the golden calf. And as it is generally agreed that this representation of the Deity was borrowed from the mysteries of Apis, it is probable that the dancing was copied from that of the Egyptians on those occasions." There was an annual dance in Shiloh on the sacred festival; and David danced before the ark. Again, in Greece the like relation existed: the original type being there, as probably in other cases, a simultaneous chanting and mimetic representation of the achievements of the god. The Spartan dances were accompanied by hymns; and in general the Greeks had "no festivals or religious assemblies but what were accompanied with songs and dances"—

both of them being forms of worship used before altars. Among the Romans, too, there were sacred dances: the Salian and Lupercalian being named as of that kind. Even in the early Christian church, dances in the choir at festivals, occasionally led by bishops, were among the forms of worship, and in some places continued down to the 18th century. The incipient separation of these once united arts from each other and from religion was early visible in Greece. Probably diverging from dances partly religious, partly warlike, as the Corybantian, came the war dances proper, of which there were various kinds; and from these resulted secular dances. Meanwhile Music and Poetry, though still joined, came to have an existence separate from dancing. The primitive Greek poems, religious in subject, were not recited but chanted; and though at first the chant of the poet was accompanied by the dance of the chorus, it ultimately grew into independence. Later still, when the poem had been differentiated into epic and lyric—when it became the custom to sing the lyric and recite the epic—poetry proper was born. As, during the same period, musical instruments were being multiplied, we may presume that music came to have an existence apart from words. And both of them were beginning to assume other forms than the religious. Facts having like implications might be cited from the histories of later times and peoples; as the practices of our Anglo-Saxon "gleemen" and Celtic bards, who sang to the harp heroic narratives versified by themselves to music of their own composition: thus uniting the now separate offices of poet, composer, vocalist, and instrumentalist. The common origin and gradual differentiation of Dancing, Poetry, and Music is thus sufficiently manifest.

Besides being displayed in the separation of these arts from one another and from religion, growing heterogeneity is also displayed in the multiplied differentiations which each of them afterwards undergoes. Just referring to the numberless kinds of dancing that have, in course of time, come into use, and to the progress of poetry, as seen in the development of the various forms of metre, of rhyme, and of general organization, let us confine our attention to music as a type of the group. As argued by Dr. Burney, and as implied by the customs of extant savages,

the first musical instruments were percussive—sticks, calabashes, tom-toms—and were used simply to mark the time of the dance. So, too, the vocal music of various semi-civilized races consists of simple phrases endlessly reiterated. In this constant repetition of the same sounds we see music in its most homogeneous form. The Egyptians had a lyre with three strings. The early lyre of the Greeks had four, constituting their tetrachord. In course of some centuries lyres of seven and eight strings came to be employed. And, by the expiration of a thousand years, they had advanced to their "great system" of the double octave. Through all which changes of course arose a greater heterogeneity of melody or rather recitative. Simultaneously came into use the different modes—Dorian, Ionian, Phrygian, Æolian, and Lydian—answering to our keys; and of these there were ultimately fifteen. As yet, however, there was but little heterogeneity in the time of their music. Instruments being used merely to accompany the voice, and vocal music being completely subordinated to words,—the singer being also the poet, chanting his own compositions and making the lengths of his notes agree with the feet of his verses—there unavoidably arose a tiresome uniformity of measure, which, as Dr. Burney says, "no resources of melody could disguise." Lacking the complex rhythm obtained by our equal bars and unequal notes, the only rhythm was that produced by the quantity of the syllables, and was of necessity monotonous. And further, the chant thus resulting being like recitative, was much less differentiated from ordinary speech than is our modern song. Nevertheless, considering the extended range of notes in use, variety of modes, the occasional variations of time consequent on changes of metre, and the multiplication of instruments, we see that music had, towards the close of Greek civilization, attained to considerable heterogeneity: not indeed as compared with our music, but as compared with that which preceded it. As yet, however, there existed nothing but serial combinations of notes (for so we must call them since they were not melodies in our sense): harmony was unknown. It was not until Christian church-music had reached some development, that music in parts was evolved; and then it came into existence through an unobtrusive differentiation. The practice which led to it was the employment of two choirs sing-

ing alternately the same air. Afterwards it became the habit (possibly first suggested by a mistake) for the second choir to commence before the first had ceased: thus producing a fugue. With the simple airs then in use, a partially harmonious fugue might not improbably result; and a very partially harmonious fugue satisfied the ears of that age, as we know from still preserved examples. The idea having once been given, the composing of airs productive of fugal harmony would naturally grow up; as in some way it *did* grow up out of this alternate choir-singing. And from the fugue to concerted music of two, three, four, and more parts, the transition was easy. Without pointing out in detail the increasing complexity that resulted from introducing notes of various lengths, from the multiplication of keys, from the use of accidentals, from varieties of time, from modulations, and so forth, it needs but to contrast music as it is with music as it was, to see how immense is the increase of heterogeneity. We see this also if, looking at music in its *ensemble*, we enumerate its many different genera and species—if we consider the divisions into vocal, instrumental, and mixed; and their subdivisions into music for different voices and different instruments—if we observe the many forms of sacred music, from the simple hymn, the chant, the canon, motet, anthem, &c., up to the oratorio; and the still more numerous forms of secular music, from the ballad up to the serenata, from the instrumental solo up to the symphony. Again, the same truth is seen on comparing any one sample of aboriginal music with a sample of modern music—even an ordinary song for the piano; which we find to be relatively very heterogeneous, not only in respect of varieties in the intervals and in the lengths of the notes, the number of different notes sounding at the same instant in company with the voice, and the variations of strength with which they are sounded and sung, but in respect of the changes of key, the changes of time, the changes of *timbre* of the voice, and the many other modifications of expression. While between the old monotonous dance chant and a grand opera of our own day, the contrast in heterogeneity is so extreme that it seems scarcely credible that the one is the ancestor of the other.

§ 126. Many further illustrations of the general law throughout

social products might be detailed. Going back to the time when the deeds of the god-king, chanted and mimetically represented in dances before his altar, were further narrated in picture writings on the walls of temples and palaces, and so constituted a rude history, we might trace the development of Literature through phases in which, as in the Hebrew Scriptures, it presents in one work, theology, cosmogony, history, biography, civil law, ethics, poetry; through other phases in which, as in the Iliad, the religious, martial, historical, the epic, dramatic, and lyric elements are similarly commingled; down to its present heterogeneous development, in which its divisions and subdivisions are so numerous and varied as to defy complete classification. Or we might track the unfolding of Science; beginning with the era in which it was not yet differentiated from Art, and was, in union with Art, the handmaid of Religion; passing through the era in which the sciences were so few and rudimentary, as to be simultaneously cultivated by the same philosophers; and ending with the era in which the genera and species are so multitudinous that few can enumerate them, and no one can adequately grasp even one genus. Or we might do the like with Architecture, with the Drama, with Dress. But doubtless the reader is already weary of illustrations, and my promise has been amply fulfilled. The advance from the simple to the complex, through successive modifications upon modifications, is seen alike in the earliest changes of the Heavens to which we can reason our way back, and in the earliest changes we can inductively establish; it is seen in the geologic and climatic evolution of the Earth, of every individual organism on its surface and in the aggregate of organisms; it is seen in the evolution of Humanity, whether contemplated in the civilized man, or in the assemblage of races; it is seen in the evolution of Society, in respect alike of its political, its religious, and its economical organization; and it is seen in the evolution of those countless concrete and abstract products of human activity, which constitute the environment of our daily life. From the remotest past which Science can fathom, up to the novelties of yesterday, an essential trait of Evolution has been the transformation of the homogeneous into the heterogeneous.

§ 127. So that the general formula arrived at in the last chapter needs supplementing. It is true that Evolution, under its primary aspect, is a change from a less coherent state to a more coherent state, consequent on the dissipation of motion and integration of matter; but this is far from being the whole truth. Along with a passage from the incoherent to the coherent, there goes on a passage from the uniform to the multiform. Such, at least, is the fact wherever Evolution is compound; which it is in the immense majority of cases. While there is a progressing concentration of the aggregate, caused either by the closer approach of the matter within its limits, or by the drawing in of further matter, or by both; and while the more or less distinct parts into which the aggregate divides and subdivides are also severally concentrating; these parts are simultaneously becoming unlike—unlike in size, or in form, or in texture, or in composition, or in several or all of these. The same process is exhibited by the whole and by its members. The entire mass is integrating and at the same time differentiating from other masses; while each member of it is also integrating and at the same time differentiating from other members.

Our conception, then, must unite these characters. As we now understand it, Evolution is definable as a change from an incoherent homogeneity to a coherent heterogeneity, accompanying the dissipation of motion and integration of matter.

## CHAPTER XVI

### THE LAW OF EVOLUTION *CONTINUED*

§ 128. But does this generalization express the whole truth? Does it include everything essentially characterizing Evolution and exclude everything else? Does it comprehend all the phenomena of secondary re-distribution which Compound Evolution presents, without comprehending any other phenomena? A critical examination of the facts will show that it does neither.

Changes from the less heterogeneous to the more heterogeneous, which are not included in what we here call Evolution, occur in every local disease. In a morbid growth we see a new differentiation. Whether this morbid growth be, or be not, more heterogeneous than the tissues in which it is seated, is not the question. The question is whether the organism as a whole is, or is not, rendered more heterogeneous by the addition of a part unlike every pre-existing part, in form, or composition, or both. To this question there can be none but an affirmative answer. Again, the earlier stages of decomposition in a dead body involve increase of heterogeneity. Supposing the chemical changes to commence in some parts sooner than in others, as they commonly do, and to affect different tissues in different ways, as they must, it seems clear that the entire body, made up of undecomposed parts and parts decomposed in various modes and degrees, has become more heterogeneous than it was. Though greater homogeneity will be the eventual result, the immediate result is the opposite. And yet this immediate result is certainly not Evolution. Other instances are furnished by social disorders and disasters. A rebellion which, while leaving some provinces undisturbed, develops itself here in secret

societies, there in public demonstrations, and elsewhere in actual conflicts, necessarily renders the society, as a whole, more heterogeneous. Or when a dearth causes commercial derangement with its entailed bankruptcies, closed factories, discharged operatives, food-riots, incendiarisms; it is manifest that as a large part of the community retains its ordinary organization displaying the usual phenomena, these new phenomena must be regarded as adding to the complexity previously existing. But such changes, so far from constituting further Evolution, are steps towards Dissolution.

So that the definition arrived at in the last chapter is an imperfect one. The changes above instanced as coming within the formula as it now stands, are so obviously unlike the rest, that the inclusion of them implies some distinction hitherto overlooked. Such further distinction we have now to supply.

§ 129. At the same time that Evolution is a change from the homogeneous to the heterogeneous, it is a change from the indefinite to the definite. Along with an advance from simplicity to complexity, there is an advance from confusion to order—from undetermined arrangement to determined arrangement. Development, no matter of what kind, exhibits not only a multiplication of unlike parts, but an increase in the clearness with which these parts are marked off from one another. And this is the distinction sought. For proof, it needs only to reconsider the instances given above. The changes constituting local disease, have no such definiteness, either in place, extent, or outline, as the changes constituting development. Though certain morbid growths are more common in some parts of the body than in others (as warts on the hands, cancer in the breasts, tubercle in the lungs), yet they are not confined to these parts; nor, where found, are they anything like so precise in their relative positions as are the normal parts around. Their sizes are very variable: they bear no such constant proportions to the body as organs do. Their forms, too, are far less specific than organic forms. And they are extremely confused in their internal structures. That is, they are in all respects comparatively indefinite. The like peculiarity may be traced in decomposition. That total

indefiniteness to which a dead body is finally reduced, is a state towards which the putrefactive changes tend from their commencement. The advancing destruction of the organic compounds blurs the tissue structures—diminishes their distinctness. From the portions that have undergone most decay, there is a gradual transition to the less decayed portions, not a sharp demarcation. And step by step the lines of organization, once so precise, disappear. Similarly with social changes of an abnormal kind. The disaffection initiating a political outbreak, implies a loosening of those ties by which citizens are bound up into distinct classes and sub-classes. Agitation, growing into revolutionary meetings, fuses ranks that are usually separated. Acts of insubordination break through the ordained limits to individual conduct, and tend to obliterate the lines between those in authority and those beneath them. At the same time arrest of trade causes artizans and others to lose their occupations; and, ceasing to be functionally distinguished, they merge into an indefinite mass. When at last there comes positive insurrection, all magisterial and official powers, all class distinctions, all industrial differences, cease: organized society lapses into an unorganized aggregate of social units. Similarly, in so far as famines and pestilences cause changes from order towards disorder, they cause changes from definite arrangements to indefinite arrangements.

Thus, then, is that increase of heterogeneity which is not a trait of Evolution, distinguished from that increase of heterogeneity which is. Though in disease and after death, individual or social, the earliest modifications are additions to the pre-existing heterogeneity, they are not additions to the pre-existing definiteness. From the outset they begin to destroy this definiteness, and gradually produce a heterogeneity that is indeterminate instead of determinate. As a city, already multiform in its variously-arranged structures of various architecture, may be made more multiform by an earthquake, which leaves part of it standing and overthrows other parts in different ways and degrees, but is at the same time reduced from orderly arrangement to disorderly arrangement; so may organized bodies be made for a time more multiform by changes which are nevertheless disorganizing changes.

And in the one case as in the other, it is the absence of definiteness which distinguishes the multiformity of regression from the multiformity of progression.

If advance from the indefinite to the definite is an essential characteristic of Evolution, we shall of course find it everywhere displayed; as in the last chapter we found displayed the advance from the homogeneous to the heterogeneous. To see whether it is so, let us now reconsider the same several classes of facts.

§ 130. Beginning, as before, with a hypothetical illustration, we have to note that each step in the evolution of the Solar System, supposing it to have originated from diffused matter, was an advance towards more definite structure. As usually conceived, the initial nebula was irregular in shape and with indistinct margins, like those of nebulæ now existing. Having partially-different proper motions, the parts of its attenuated substance, while being drawn together, generated, by the averaging of their motions, as well as by changes in the directions of these motions, a certain angular momentum; and the entire mass as it concentrated and acquired rotation must have assumed the form of an oblate spheroid which with every increase of density, became more specific in outline, and had its surface more distinctly marked off from the surrounding void. Simultaneously, the constituent portions of nebulous matter, instead of moving round their common centre of gravity in various planes, as they would at first do, must have had these planes more and more merged into a single plane, that became less vague as the concentration progressed—became gradually defined.

According to the hypothesis, change from indistinct characters to distinct ones, was repeated in the evolution of planets and satellites. A gaseous spheroid is less definitely limited than a liquid spheroid, since it is subject to larger undulations of surface, and to greater distortions of general form; and, similarly, a liquid spheroid, covered as it must be with waves of various magnitudes, tidal and other, is less definite than a solid spheroid. The decrease of oblateness which goes along with increase of integration, brings relative definiteness of other elements. A concentrating planet having an axis inclined to the plane of its orbit, must, while very

oblate, have its plane of rotation much disturbed by external attractions; whereas its approach to a spherical form, involves a smaller processional motion, and less marked variations in the direction of its axis.

With progressing settlement of the space-relations, the force-relations simultaneously become more settled; and the exact calculations of physical astronomy show us how definite these force-relations now are. In short, it needs but to think of the contrast between the chaos of the primitive nebula and the ordered relations of the Solar System in the sizes, shapes, motions and combined inter-actions of its members, to see that increase of definiteness has been a marked trait of its evolution.

§ 131. From that primitive molten state of the Earth inferable from geological data as well as from the nebular hypothesis (probably a liquid shell having a nucleus of gases above the "critical point" of temperature, kept by pressure at a density as great as that of the superjacent liquid) the transition to its existing state has been through stages in which the characters became more determinate. A liquid spheroid is less specific than a solid spheroid in having no fixed distribution of parts. Currents of molten matter, though kept to certain general circuits by the conditions of equilibrium, cannot, in the absence of solid boundaries, be precise in their limits and directions: all parts must be in motion with respect to other parts. But a superficial solidification, even though partial, is a step towards the establishment of definite relations of position. In a thin crust, however, often ruptured by disturbing forces, and moved by every tidal undulation, fixity of relative position can be but temporary. Only as the crust thickens can there arise distinct and settled geographical positions. Observe, too, that when, on a surface adequately cooled, there begins to precipitate the water floating above as vapour, the deposits cannot maintain definiteness either of state or place. Falling on a solid envelope not thick enough to preserve anything beyond slight variations of level, the water must form small and shallow pools over the coolest areas; which areas must pass insensibly into others that are too hot to allow condensation. With progressing refrigeration, however,—with a thickening crust,

a consequent formation of larger elevations and depressions, and the precipitation of more atmospheric water, there comes an arrangement of parts which is comparatively fixed; and the definiteness of position increases, until there result continents and oceans—a distribution that is not only topographically settled, but presents separations of land from water more definite than could have existed when all the uncovered areas were low islands with shelving beaches, over which the tide ebbed and flowed to great distances.

Respecting the characters classed as geological, we may draw kindred inferences. While the Earth's crust was thin, mountain-chains were impossibilities: there could not have been long and well-defined axes of elevation, with distinct water-sheds and areas of drainage. Moreover, the denudation of small islands by small rivers, and by tidal streams both feeble and narrow, would produce no clearly-marked sedimentary strata. Confused and varying masses of detritus, such as we now find at the mouths of brooks, must have been the prevailing formations. And these could give place to distinct strata, only as there arose continents and oceans, with their great rivers, long coast-lines, and wide-spreading marine currents.

There must simultaneously have resulted more definite meteorological conditions. Differences of climates and seasons grew relatively decided as the heat derived from the Sun became distinguishable from the proper heat of the Earth; and the production of more specific conditions in each locality was aided by increasing permanence in the distribution of lands and seas. These are conclusions sufficiently obvious.

§ 132. We come now to the evidence yielded by organic bodies. In place of deductive illustrations, we shall here find illustrations which have been inductively established, and are therefore less open to criticism. The course of mammalian development, for example, will supply us with numerous proofs ready-described by embryologists.

The first change which the ovum of a mammal undergoes after repeated segmentation has reduced it to a mulberry-like mass, is the appearance of a distinction between the peripheral or epiblastic

cells of this mass and the internal or hypoblastic cells. While growing rapidly the cluster of cells becomes hollow, and the blastodermic vesicle so formed presents a definite contrast between the outer layer, or epiblast, and its contents. The mass of hypoblast cells, having at first an indefinite, lens-like figure attached to the inside of the epiblast, spreads out and flattens into a membrane, the boundary of which is irregular—indefinite alike in form and constitution. And then the middle or thicker part presently becomes an opaque circular spot constituting the embryonic area: a spot which gradually acquires a pronounced outline. In the centre of this there at length comes the primitive streak or trace, which, as its name implies, is indefinite but by-and-by "becomes a more pronounced structure." Within this streak or trace the vertebrate axis first shows itself. Beginning as a shallow groove, it becomes slowly more pronounced; its sides grow higher; their summits overlap and at last unite; and so the indefinite groove passes into a definite tube, forming the vertebral canal. In this vertebral canal the leading divisions of the brain are at first discernible only as slight bulgings; while the proto-vertebræ commence as indistinct modifications of the tissue bounding the canal. Meanwhile in kindred ways the indefinite outspread membrane through which are absorbed the materials for the unfolding structures around is changed into a definite alimentary canal. And in an analogous manner the entire embryo, which at first lies outspread on the yelk-sack, gradually rises up from it, and by the unfolding of its ventral region becomes a separate mass, definitely outlined, connected with the yelk-sack only by a narrow duct.

These changes, through which the general structure is marked out with slowly-increasing precision, are paralleled in the evolution of each organ. The liver commences by multiplication of certain cells in the wall of the intestine. The thickening produced by this multiplication, "increases so as to form a projection upon the exterior of the canal—a hollow bud"; and at the same time that the organ grows and becomes distinct from the intestine, the channels running through it are transformed into ducts having clearly-marked walls. Similarly, certain cells of the external coat of the alimentary canal at its upper portion, accumulate into

lumps or buds from which the lungs are developed; and these, in their general outlines and detailed structure, acquire distinctness step by step. But even were no examples given, it would be undeniable that since a simple cluster of similar cells grows into head, trunk, and limbs of distinct shapes, each made up of many organs containing parts severally having clear outlines and composed of specific tissues, increase of definiteness has been a leading trait of the transformation.

Changes of this order continue long after birth; and, in the human being, are some of them not completed till middle life. During youth, most of the articular surfaces of the bones remain rough and fissured—the calcareous deposit ending irregularly in the surrounding cartilage. But between puberty and the age of thirty, these articular surfaces are finished off into smooth, hard, sharply-cut "epiphyses." Generally, indeed, we may say that increase of definiteness continues when there has ceased to be any appreciable increase of heterogeneity. And there is reason to think that those modifications which take place after maturity, bringing about old age and death, are modifications of this nature; since they cause rigidity of structure, a consequent restriction of movement and of functional pliability, a gradual narrowing of the limits within which the vital processes go on, ending in an organic adjustment too precise—too narrow in its margin of possible variation to permit the requisite adaptation to changes of external conditions.

§ 133. To give clear proof that the Earth's Flora and Fauna, regarded either as wholes or in their separate species, have progressed in definiteness, is no more possible than it was to prove that they have progressed in heterogeneity: the facts are not sufficient. If, however, we allow ourselves to reason from the hypothesis, now daily rendered more probable, that every species has arisen through the accumulation of modifications upon modifications, just as every individual arises; we shall see that there must have been a progress from the indeterminate to the determinate, both in the particular forms and in the groups of forms.

We may set out with the significant fact that the lowest

organisms (which are analogous in structure to the germs of all higher ones) have so little definiteness that it is difficult, if not impossible, to decide whether they are plants or animals. Respecting sundry of them there are unsettled disputes between zoologists and botanists. Note next that among the *Protozoa*, great indefiniteness of shape is general. Of sundry shell-less Rhizopods the form is so irregular as to admit of no description: it is neither alike in any two individuals nor in the same individual at successive moments. By aggregation of *Protozoa*, are produced, among other creatures, the Sponges, most of which are indefinite in size, in contour, in internal arrangement; and such more definite aggregates as the *Hydra* are made indefinite both by the great differences between their contracted and expanded states and by their reproductive developments. As further showing how relatively indeterminate are the simplest organisms, it may be mentioned that their structures vary greatly with surrounding conditions: so much so that, among the *Protozoa* and *Protophyta*, many forms which were once classed as distinct species, and even as distinct genera, are found to be merely varieties of one species. If, now, we call to mind how precise in their traits are the highest organisms—how sharply cut their outlines, how invariable their proportions, and how comparatively constant their structures under changed conditions; we cannot deny that greater definiteness is one of their characteristics. If they have been evolved out of lower organisms, increase of definiteness has been an accompaniment of their evolution.

That, in course of time, species have become more sharply marked off from other species, genera from genera, and orders from orders, is a conclusion not admitting of a more positive establishment than the foregoing. If, however, species and genera and orders have arisen by evolution, then, as Mr. Darwin shows, the contrasts between groups must have become greater. Disappearance of intermediate forms, less fitted for special spheres of existence than the extreme forms they connected, must have made the differences between the extreme forms decided; and so, from indistinct varieties, must have been produced distinct species: an inference which is in harmony with what we know respecting races of men and races of domestic animals.

§ 134. The successive phases through which societies pass, obviously display the progress from indeterminate arrangements to determinate arrangements. A wandering tribe of savages, being fixed neither in its locality nor in its internal distribution, is far less definite in the relative positions of its parts than a nation. In such a tribe the social relations are confused and unsettled. Political authority is vague. Distinctions of rank are neither clearly marked nor impassable. And save in the different occupations of men and women, there are no decided industrial divisions. Only in tribes of considerable size, which have enslaved other tribes, is economic differentiation distinct.

But one of these primitive societies that evolves, becomes step by step more specific. Increasing in size, consequently ceasing to be so nomadic, and restricted in its range by neighbouring societies, it acquires, after prolonged border warfare, a settled territorial boundary. The distinction between the ruling race and the people, sometimes amounts, in the popular belief, to a difference of nature. The warrior-class attains a perfect separation from classes devoted to the cultivation of the soil or to other occupations regarded as servile. And there arises a priesthood which is defined in its rank, its functions, its privileges. This sharpness of definition, growing both greater and more variously exemplified as societies advance to maturity, is extremest in those which have reached their full development or are declining. Of ancient Egypt we read that its social divisions were precise and its customs rigid. Recent investigations make it more than ever clear that among the Assyrians and surrounding peoples, not only were the laws unalterable, but even the minor habits, down to those of domestic routine, possessed a sacredness which insured their permanence. In India at the present day, the unchangeable distinctions of caste, not less than the constancy in modes of dress, industrial processes, and religious observances, show how definite are the arrangements where the antiquity is great. Nor does China, with its long-settled political organization, its elaborate and precise conventions, fail to exemplify the same truth.

The successive phases of our own and adjacent societies, furnish facts somewhat different in kind but similar in meaning. Originally, monarchical authority was more baronial, and baronial

authority more monarchical, than afterwards. Between modern priests and the priests of old times, who while officially teachers of religion were also warriors, judges, architects, there is a marked difference in definiteness of function. And among the people engaged in productive occupations, like contrasts hold: the regulative parts have become definitely distinct from the operative parts and the distributive parts from both. The history of our constitution, reminding us how the powers of King, Lords, and Commons, have been gradually settled, describes analogous changes. Countless facts bearing the like construction meet us when we trace the development of legislation; in the successive stages of which we find statutes gradually rendered more specific in their applications to particular cases. Even now each new law, beginning as a vague proposition, is, in the course of enactment, elaborated into specific clauses; and only after its interpretation has been established by judges' decisions in courts of justice, does it reach its final definiteness. From the annals of minor institutions like evidence may be gathered. Religious, charitable, literary, and all other societies, starting with ends and methods roughly sketched out and easily modifiable, show us how, by the accumulation of rules and precedents, the purposes become more precisely formulated and the modes of action more restricted; until at last decay follows a fixity which admits of no adaptation to new conditions. Should it be objected that among civilized nations there are examples of decreasing definiteness, (instance the breaking down of limits between ranks,) the reply is that such apparent exceptions are the accompaniments of a social metamorphosis—a change from the military type of social structure to the industrial type, during which old lines of structure are disappearing and new ones becoming more marked.

§ 135. All organized results of social action—all superorganic structures, pass through parallel phases. Being, as they are, objective products of subjective processes, they must display corresponding changes; and that they do this, the cases of Language, of Science, of Art, clearly prove.

Strike out from our sentences everything but nouns and verbs, and there stands displayed the vagueness characterizing un-

developed tongues. Each inflection of a verb, or addition by which the case of a noun is marked, by limiting the conditions of action or of existence, enables men to express their thoughts more precisely. That the application of an adjective to a noun or an adverb to a verb, narrows the class of things or changes indicated, implies that the additional word serves to make the proposition more distinct. And similarly with other parts of speech.

The like effect results from the multiplication of words of each order. When the names for objects, and acts, and qualities, are but few, the range of each is proportionately wide, and its meaning therefore unspecific. The similes and metaphors so much used by aboriginal races, indirectly and imperfectly suggest ideas which they cannot express directly and perfectly from lack of words. Or to take a case from ordinary life, if we compare the speech of the peasant who, out of his limited vocabulary, can describe the contents of the bottle he carries, only as "doctor's stuff" which he has got for his "sick" wife, with the speech of the physician, who tells those educated like himself the particular composition of the medicine and the particular disorder for which he has prescribed it; we have vividly brought home to us the precision which language gains by the multiplication of terms.

Again, in the course of its evolution, each tongue acquires a further accuracy through processes which fix the meaning of each word. Intellectual intercourse slowly diminishes laxity of expression. By-and-by dictionaries give definitions. And eventually, among the most cultivated, indefiniteness is not tolerated, either in the terms used or in their grammatical combinations.

Once more, languages considered as wholes become more sharply marked off from one another, and from their common parent; as witness, in early times, the clear distinction that arose between the two connate languages Greek and Latin, and in later times the divergence of three Latin dialects into Italian, French, and Spanish.

§ 136. In his *History of the Inductive Sciences*, Dr. Whewell says that the Greeks failed in physical philosophy because their "ideas were not distinct, and appropriate to the facts." I do not quote this remark for its luminousness; since it would be equally

proper to ascribe the indistinctness and inappropriateness of their ideas to the imperfection of their physical philosophy; but I quote it because it serves as good evidence of the indefiniteness of primitive science. The same work and its fellow, *The Philosophy of the Inductive Sciences*, yield other evidences equally good, because equally independent of any such hypothesis as is here to be established. Respecting mathematics, we have the fact that geometrical theorems grew out of empirical methods; and that these theorems, at first isolated, did not acquire the clearness which demonstration gives, until they were arranged by Euclid into a series of dependent propositions. At a later period, the same general truth was exemplified in the progress from the "method of exhaustions" and the "method of indivisibles" to the "method of limits"; which is the central idea of the infinitesimal calculus. In early mechanics may be traced a dim perception that action and reaction are equal and opposite; though, for ages after, this truth remained unformulated. And similarly, the property of inertia, though not distinctly comprehended until Kepler lived, was vaguely recognized long before. "The conception of statical force," "was never presented in a distinct form till the works of Archimedes appeared"; and "the conception of accelerating force was confused, in the mind of Kepler and his contemporaries, and did not become clear enough for purposes of sound scientific reasoning before the succeeding century." To which specific assertions may be added the general remark, that "terms which originally, and before the laws of motion were fully known, were used in a very vague and fluctuating sense, were afterwards limited and rendered precise." When we turn from abstract scientific conceptions to the concrete previsions of science, of which astronomy furnishes numerous examples, a like contrast is visible. The times at which celestial phenomena will occur, have been predicted with ever-increasing accuracy. Errors once amounting to days are now diminished to seconds. The correspondence between the real and supposed forms of orbits has been gradually rendered more precise. Originally thought circular, then epicyclical, then elliptical, orbits are now ascertained to be curves which always deviate from perfect ellipses, and are ever undergoing changes.

But the general advance of Science in definiteness is best shown

by the contrast between its qualitative stage and its quantitative stage. At first the facts ascertained were that between such and such phenomena some connexion existed—that the appearances *a* and *b* always occurred together or in succession; but it was known neither what was the nature of the relation between *a* and *b*, nor how much of *a* accompanied so much of *b*. The development of Science has in part been the reduction of these vague connexions to distinct ones. Most relations have been classed as mechanical, chemical, thermal, electric, magnetic, &c.; and we have learnt to infer the relative amounts of the antecedents and consequents with exactness. Of illustrations, some furnished by physics have been given, and from other sciences plenty may be added. We have ascertained the constituents of numerous compounds which our ancestors could not analyze, and of a far greater number which they never even saw; and the combining equivalents of the elements are now accurately calculated. Physiology shows advance from qualitative to quantitative prevision in ascertaining definite relations between organic products and the materials consumed; as well as in measurement of functions by spirometer and sphygmograph. By Pathology it is displayed in the use of the statistical method of determining the sources of diseases, and the effects of treatment. In Botany and Zoology, the numerical comparisons of Floras and Faunas, leading to specific conclusions respecting their sources and distributions, illustrate it. And in Sociology, questionable as are many conclusions drawn from the classified sum-totals of the census, from the Board-of-Trade tables, and from criminal returns, it must be admitted that these imply a progress towards more precise conceptions of social phenomena.

That an essential characteristic of advancing Science is increase in definiteness, appears indeed almost a truism, when we remember that Science may be described as definite knowledge, in contradistinction to that indefinite knowledge possessed by the uncultured. And if, as we cannot question, Science has, in the course of ages, been evolved out of this indefinite knowledge of the uncultured, then, the gradual acquirement of that great definiteness which now distinguishes it, must have been a leading trait in its evolution.

§ 137. The Arts, industrial and æsthetic, supply illustrations perhaps still more striking. Palæolithic flint implements show the extreme want of precision in men's first handiworks. Though a great advance on these is seen in the tools and weapons of existing savage tribes, yet an inexactness in forms and fittings distinguishes such tools and weapons from those of civilized races. In a smaller degree, the productions of the less-advanced nations are characterized by like defects. A Chinese junk, with all its contained furniture and appliances, nowhere presents a line that is quite straight, a uniform curve, or a true surface. Nor do the utensils and machines of our ancestors fail to exhibit a similar inferiority to our own. An antique chair, an old fireplace, a lock of the last century, or almost any article of household use that has been preserved for a few generations, proves by contrast how greatly the industrial products of our time excel those of the past in their accuracy. Since planing machines have been invented, it has become possible to produce absolutely straight lines, and surfaces so truly level as to be air-tight when applied to each other. While in the dividing-engine of Troughton, in the micrometer of Whitworth, in microscopes that show fifty thousand divisions to the inch, and in ruled divisions up to 200,000, we have an exactness as far exceeding that reached in the works of our great-grandfathers, as theirs exceeded that of the aboriginal celt-makers.

In the Fine Arts there has been a parallel progress. From the rudely-carved and painted idols of savages, through the early sculptures characterized by limbs without muscular detail, wooden-looking drapery, and faces devoid of individuality, up to the later statues of the Greeks or some of those now produced, the increased accuracy of representation is conspicuous. Compare the mural paintings of the Egyptians with the paintings of mediæval Europe, or these with modern paintings, and the more precise rendering of the appearances of objects is manifest. It is the same with fiction and the drama. In the marvellous tales current among Eastern nations, in the romantic legends of feudal Europe, as well as in the mystery-plays and those immediately succeeding them, we see great want of correspondence to the realities of life; alike in the predominance of supernatural events, in the extremely improbable occurrences, and in the vaguely-indicated personages.

Along with social advance, there has been a progressive diminution of unnaturalness—an approach to truth of representation. And now, cultivated men applaud novels and plays in proportion to the fidelity with which they exhibit characters; improbabilities, like the impossibilities which preceded them, are disallowed; and we see fewer of those elaborate plots which life rarely furnishes: realities are more definitely pictured.

§ 138. Space might be filled with evidences of other kinds, but the basis of induction is already wide enough. Proof that all Evolution is from the indefinite to the definite, we find not less abundant than proof that all Evolution is from the homogeneous to the heterogeneous.

It should, however, be added that this advance in definiteness is not a primary but a secondary phenomenon—is a result incidental on other changes. The transformation of a whole that was originally diffused and uniform into a concentrated combination of multiform parts, implies progressive separation both of the whole from its environment and of the parts from one another. While this is going on there must be indistinctness. Only as the whole gains density, does it become sharply marked off from the space or matter lying outside of it; and only as each division draws into its mass those peripheral portions which are at first imperfectly disunited from the peripheral portions of neighbouring divisions, can it acquire anything like a precise outline. That is to say, the increasing definiteness is a concomitant of the increasing consolidation, general and local. While the secondary re-distributions are ever adding to the heterogeneity, the primary re-distribution, while augmenting the integration, is incidentally giving distinctness to the increasingly-unlike parts as well as to the aggregate of them.

But though this universal trait of Evolution is a necessary accompaniment of the traits set forth in preceding chapters, it is not expressed in the words used to describe them. It is therefore needful further to modify our formula. The more specific idea of Evolution now reached is—a change from an indefinite, incoherent homogeneity, to a definite coherent heterogeneity, accompanying the dissipation of motion and integration of matter.

## CHAPTER XVII

### THE LAW OF EVOLUTION *CONCLUDED*

§ 139. The conception of Evolution elaborated in the foregoing chapters, is still incomplete. True though it is, it is not the whole truth. The transformations which all things undergo during the ascending phases of their existence, we have contemplated under three aspects; and by uniting these three aspects as simultaneously presented, we have formed an approximate idea of the transformations. But there are concomitant changes about which nothing has yet been said, and which, though less conspicuous, are no less essential.

For thus far we have attended only to the re-distribution of Matter, neglecting the accompanying re-distribution of Motion. Distinct or tacit reference has, indeed, repeatedly been made to the dissipation of Motion, that goes on along with the concentration of Matter; and were all Evolution absolutely simple, the total fact would be contained in the proposition that as Motion dissipates Matter concentrates. But while we have recognized the *ultimate* re-distribution of the Motion, we have passed over its *proximate* re-distribution. Though something has from time to time been said about the escaping motion, nothing has been said about the motion which does not escape. In proportion as Evolution becomes compound—in proportion as an aggregate retains, for a considerable time, such quantity of motion as permits secondary re-distributions of its component matter, there necessarily arise secondary re-distributions of its retained motion. As fast as the parts are transformed, there goes on a transformation of the sensible or insensible motions possessed by the parts. They cannot become more integrated, either individu-

ally or as a combination, without their motions, individual or combined, becoming more integrated. There cannot arise among them heterogeneities of size, of form, of quality, without there also arising heterogeneities in the amounts and directions of their motions, or the motions of their molecules. And increasing definiteness of the parts implies increasing definiteness of their motions. In short, the rhythmical actions going on in each aggregate, must differentiate and integrate at the same time that the structures do so.

§ 139*a*. The general theory of this re-distribution of the retained motion, must here be briefly stated. Properly to supplement our conception of Evolution under its material aspect by a conception of Evolution under its dynamical aspect, we have to recognize the source of the integrated motions that arise, and to see how their increased multiformity and definiteness are necessitated.

If Evolution is a passage from a diffused state to an aggregated state, then the motions of the celestial bodies must have resulted from the uncancelled motions of their once dispersed components. Along with the molecular motions everywhere active, there were molar motions of those vast streams of nebulous matter which were generated during the process of concentration—molar motions of which large portions were gradually dissipated as heat, leaving undissipated portions. But since the molar motions of these nebulous streams were constituted from the motions of multitudinous incoherent gaseous parts severally moving more or less independently, it follows that when aggregation into a liquid and finally solid celestial mass was reached, these partially independent motions of the incoherent parts became merged into the motion of the whole: or, in other words, unintegrated motions became an integrated motion. While we must leave in the shape of hypothesis the belief that the celestial motions have thus originated, we may see, as a matter of fact, that the integration of insensible motions originates all sensible motions on the Earth's surface. As all know, the denudation of lands and deposit of new strata, are effected by water while descending to the sea, or during the arrest of those undulations produced on it by winds; and, as

before said, the elevation of water to the height whence it fell, is due to solar heat, as is also the genesis of those aërial currents which drift it about when evaporated and agitate its surface when condensed. That is to say, the molecular motion of the ethereal medium is transformed into the motion of gases, thence into the motion of liquids, and thence into the motion of solids: stages in each of which a certain amount of molecular motion is lost and an equivalent motion of masses gained. It is the same with organic movements. Certain rays issuing from the Sun, enable the plant to reduce special elements existing in gaseous combinations around it to solid forms—enable the plant, that is, to grow and carry on its functional changes. And since growth, equally with circulation of sap, is a mode of sensible motion, while those rays which have been expended in generating both consist of insensible motions, we have here, too, a transformation of the kind alleged. Animals, derived as their forces are, directly or indirectly, from plants, carry this transformation a step further. The automatic movements of the viscera, together with the voluntary movements of the limbs and body at large, arise at the expense of certain molecular movements throughout the nervous and muscular tissues; and these originally arose at the expense of certain other molecular movements propagated by the Sun to the Earth; so that both the structural and functional motions which organic Evolution displays, are motions of aggregates generated by the arrested motions of units. Even with the aggregates of these aggregates the same rule holds. For among associated men the progress is ever towards a merging of individual actions in the actions of corporate bodies. In militant life this is seen in the advance from the independent fighting of separate warriors to the combined fighting of regiments, and in industrial life in the advance from the activities of separate workers to the combined activities of factory hands. So is it, too, when instead of acting alone citizens act in bodies—companies, unions, associations, &c. While, then, during Evolution the escaping motion becomes, by widening dispersion, more disintegrated, the motion that is for a time retained becomes more integrated; and so, considered dynamically, Evolution is a decrease in the relative movements of parts and an increase in the relative

movements of wholes—using the words parts and wholes in their most general senses. The advance is from the motions of simple molecules to the motions of compound molecules; from molecular motions to the motions of masses; and from the motions of smaller masses to the motions of larger masses.

The accompanying change towards greater multiformity among the retained motions, takes place under the form of an increased variety of rhythms. A multiplication of rhythms must accompany a multiplication in the degrees and modes of aggregation, and in the relations of the aggregated masses to incident forces. The degree or mode of aggregation will not, indeed, affect the rate or extent of rhythm where the incident force increases as the aggregate increases, which is the case with gravitation: here the only cause of variation in rhythm is difference of relation to the incident force; as we see in a pendulum which, though unaffected in its movements by a change in the weight of the bob, alters its rate of oscillation when its length is altered or when, otherwise unchanged, it is taken to the equator. But in all cases where the incident forces do not vary as the masses, every new order of aggregation initiates a new order of rhythm: witness the conclusion drawn from the recent researches into radiant heat and light, that the molecules of different gases have different rates of undulation.* So that increased multiformity in the arrangement of matter, necessarily generates increased multiformity of rhythm; both through increased variety in the sizes and forms of aggregates, and through increased variety in their relations to the forces which move them. That these motions, as they become more integrated and more heterogeneous, must become more definite is a proposition that need not detain us. In proportion as any part of an evolving whole segregates and consolidates, and in so doing loses the relative mobility of its components, its aggregate motion must obviously acquire distinctness.

Here, then, to complete our conception of Evolution, we must contemplate throughout the Cosmos, these metamorphoses of retained motion which accompany the metamorphoses of component matter. We may do this with comparative brevity: the reader having now become so familiar with the mode of looking at the facts,

* This was written in 1867.

that less illustration will suffice. To save space, it will be convenient to deal with the several aspects of the metamorphoses at the same time.

§ 140. Masses of diffused matter moving towards a common centre, from many points at many distances with many degrees of indirectness, must carry into the nebulous mass eventually formed numerous momenta unlike in their amounts and directions. As the integration progresses, such parts of these momenta as conflict are mutually neutralized, and dissipated as heat. Unless the original distribution is quite symmetrical, which is infinitely improbable, rotation will result. The mass having at first unlike angular velocities at the periphery and at various distances from the centre, will have its differences of angular velocity gradually reduced; advancing towards a final state, now nearly reached by the Sun, in which the angular velocity of the whole mass is the same —in which the motion is integrated. So, too, with each planet and satellite. Progress from the motion of a nebulous ring, incoherent and admitting of much relative motion within its mass, to the motion of a dense spheroid is progress to a motion that is completely integrated. The rotation, and the translation through space, severally become one and indivisible. Meanwhile, there has been established that further integration displayed by the motions of the Solar System as a whole. Locally in each planet and its satellites, and generally in the Sun and the planets, we have a system of simple and compound rhythms, with periodic and secular variations, forming together an integrated set of movements.

Along with advancing integration of the motions there has gone advance in the multiformity and distinctness of them. The matter which, in its original diffused state, had movements that were confused, indeterminate, or without sharply-marked distinctions, has, during the evolution of the Solar System, acquired definitely heterogeneous movements. The periods of revolution of all the planets and satellites are unlike; as are also their times of rotation. Out of these definitely heterogeneous motions of a simple kind arise others that are complex, but still definite;—as those produced by the revolutions of satellites compounded with the revolutions of

their primaries; as those of which precession is the result; and as those which are known as perturbations. Each additional complexity of structure has caused additional complexity of movements; but still, a definite complexity, as is shown by having calculable results.

§ 141. While the Earth's surface was molten, the currents in the voluminous atmosphere surrounding it, mainly of ascending heated gases and of descending precipitated liquids, must have been local, numerous, indefinite, and but little distinguished from one another. But when after a vast period the surface, now solidified, had so far cooled that solar radiation began to cause appreciable differences of temperature between the equatorial and polar regions, an atmospheric circulation from poles to equator and from equator to poles must have slowly established itself: other vast moving masses of air becoming, at last, trade-winds and other such permanent definite currents. These integrated motions, once comparatively homogeneous, were rendered heterogeneous as great islands and continents arose, to complicate them by periodic winds, caused by the varied heating of wide tracts of land at different seasons. Rhythmical motions of a constant and simple kind, were, by increasing multiformity of the Earth's surface, differentiated into an involved combination of constant and recurrent rhythmical motions, joined with smaller motions that are irregular.

Parallel changes must have taken place in the motions of water. On a thin crust, admitting of but small elevations and depressions, and therefore of but small lakes and seas, none beyond small local circulations were possible. But along with the formation of continents and oceans, came the vast movements of water from warm latitudes to cold and from cold to warm—movements increasing in amount, in definiteness, and in variety of distribution, as the features of the Earth's surface became larger and more contrasted. The like holds with drainage waters. The tricklings of insignificant streams over small tracts of land, were once alone possible; but as fast as wide areas came into existence, the motions of many tributaries became massed into the motions of great rivers; and instead of motions very much alike, there arose motions considerably varied.

Nor can we well doubt that the changes in the Earth's crust itself, have presented an analogous progress. Small, numerous, local, and like one another, while the crust was thin, the movements of elevation and subsidence must, as the crust thickened, have extended over larger areas, must have continued for longer eras in the same directions, and must have been made more unlike in different regions by local differences of structure.

§ 142. In organisms the advance towards a more integrated, heterogeneous, and definite distribution of the retained motion, which accompanies the advance towards a more integrated, heterogeneous, and definite distribution of the component matter, is mainly what we understand as the development of functions. All active functions are either sensible movements, as those produced by contractile organs; or such insensible movements as those propagated through nerves; or such insensible movements as those by which, in secreting organs, molecular re-arrangements are effected, and new combinations of matter produced. And during evolution functions, like structures, become more consolidated individually, as well as more combined with one another, at the same time that they become more multiform and more distinct.

The nutritive juices in animals of low types move hither and thither through the tissues quite irregularly, as local strains and pressures determine: in the absence of a true blood and a distinct vascular system, there is no definite circulation. But along with the structural evolution which establishes a good apparatus for distributing blood, there goes on the functional evolution which establishes large and rapid movements of blood, definite in their courses and definitely distinguished as efferent and afferent, and that are heterogeneous both in their directions and in their characters: being here divided into gushes and there continuous.

Again, accompanying the structural differentiations and integrations of the alimentary canal, there arise differentiations and integrations both of its mechanical movements and its actions of a non-mechanical kind. Along an alimentary canal of a primitive type there pass, almost uniformly from end to end, waves of constriction. But in a well-organized alimentary canal, the waves of constriction are widely unlike at different parts, in their kinds,

strengths, and rapidities. In the œsophagus they are propulsive in their office, and travelling with considerable speed, take place at intervals during eating, and then do not take place till the next meal. In the stomach another modification of this originally uniform action occurs: the muscular constrictions are powerful, and continue during the long periods that the stomach contains food. Throughout the upper intestines, again, a further difference shows itself—the waves travel along without cessation but are relatively moderate. Finally, in the rectum this rhythm departs in another way from the common type: quiescence, lasting for many hours, is followed by a series of strong contractions. Meanwhile, the essential actions which these movements aid, have been growing more definitely heterogeneous. Secretion and absorption are no longer carried on in much the same way from end to end of the tube; but the general function divides into various subordinate functions. The solvents and ferments furnished by the coats of the canal and the appended glands become widely unlike at upper, middle, and lower parts of the canal; implying different kinds of molecular changes. Here the process is mainly secretory, there it is mainly absorbent, and in other places, as in the œsophagus, neither secretion nor absorption takes place to any appreciable extent. While these and other internal motions, sensible and insensible, are being rendered more various, and severally more integrated and more distinct, there is advancing the integration by which they are united into local groups of motions and a combined system of motions. While the function of alimentation subdivides, its subdivisions become co-ordinated, so that muscular and secretory actions go on in concert, and so that excitement of one part of the canal sets up excitement of the rest. Moreover, the whole alimentary function, while it supplies matter for the circulatory and respiratory functions, becomes so integrated with them that it cannot for a moment go on without them. And, as evolution advances, all three of these fundamental functions fall into greater subordination to the nervous functions—depend more and more on the due amount of nervous discharge; while at the same time their motions become co-ordinated, or in a sense integrated, with those of the nervo-muscular system, on which they depend for the supply of materials.

When we trace up the functions of motor organs the same truth discloses itself. Microscopic creatures are moved through the water by the oscillations of cilia, here large and single or double, and here smaller and numerous; and various larger forms, as the *Turbellaria*, progress by ciliary action over solid surfaces. These motions of cilia are, in the first place, severally very minute; in the second place, they are homogeneous; and in the third place, there is but little definiteness in them individually, or in their joint product, which is mostly a random change of position not directed to any selected point. Contrasting this ciliary action with the action of developed locomotive organs, we see that instead of many small or unintegrated movements there are a few comparatively large or integrated movements; that actions all alike are replaced by actions partially or wholly unlike; and that instead of being very feebly or almost accidentally co-ordinated, their definite co-ordination renders the motions of the body as a whole, precise. A parallel contrast, less extreme but sufficiently decided, is seen when we pass from the lower types of creatures with limbs to the higher types of creatures with limbs. The legs of a Centipede have motions that are numerous, small, and homogeneous; and are so little integrated that when the creature is divided and subdivided, the legs belonging to each part propel that part independently. But in one of the higher *Arthropoda*, as a Crab, the relatively few limbs have motions which are comparatively large in their amounts, which are considerably unlike one another, and which are integrated into total bodily movements of much definiteness.

§ 143. The last illustrations introduce us to illustrations of the kind classed as mental. They are the physiological aspects of the simpler among those functions which, under a more special and complex aspect, we distinguish as psychological. The phenomena subjectively known as changes in consciousness, are objectively known as nervous excitations and discharges, which science now interprets into modes of motion. Hence, in following up organic evolution, advance of the retained motion alike in integration, in heterogeneity, and in definiteness, may be expected to show itself both in the visible nervo-muscular actions and in the correlative

mental changes. We may conveniently look at the facts as exhibited during individual evolution, before looking at them as exhibited in general evolution.

The progress of a child in speech very clearly displays the transformation. Infantine noises are comparatively homogeneous; alike as being severally long-drawn and nearly uniform from end to end, and as being constantly repeated with but little variation of quality. They are quite un-coördinated—there is no integration of them into compound sounds. They are inarticulate, or without those definite beginnings and endings and joinings characterizing words. Progress shows itself first in the multiplication of the inarticulate sounds: the extreme vowels are added to the medium vowels, and the compound to the simple. Presently the movements which form the simpler consonants are achieved, and some of the sounds become sharply cut; but this definiteness is partial, for only initial consonants being used, the sounds end vaguely. While an approach to distinctness thus results, there also results, by combination of different consonants with the same vowels, an increase of heterogeneity; and along with the complete distinctness which terminal consonants give, arises a further great addition to the number of unlike sounds produced. The more difficult consonants and the compound consonants, imperfectly articulated at first, are by-and-by articulated with precision; and hence arises another multitude of different and definite words—words that imply many kinds of vocal movements, severally performed with exactness, as well as perfectly integrated into complex groups. The subsequent advance to dissyllables and polysyllables, and to involved combinations of words, shows the still higher degree of integration and heterogeneity eventually reached by these organic motions. The acts of consciousness correlated with these nervo-muscular acts, of course go through parallel phases; and the advance from childhood to maturity yields daily proof that the changes which, on their physical side are nervous processes, and on their mental side are processes of thought, become more various, more defined, more coherent. At first the intellectual functions are much alike in kind—recognitions and classifications of simple impressions alone go on; but in course of time these functions become multiform. Reasoning grows distinguish-

able, and eventually we have conscious induction and deduction; deliberate recollection and deliberate imagination are added to simple unguided association of ideas; more special modes of mental action, as those which result in mathematics, music, poetry, arise; and within each of these divisions the mental movements are ever being further differentiated. In definiteness it is the same. At first the infant makes its observations so inaccurately that it fails to distinguish individuals. The child errs continually in its spelling, its grammar, its arithmetic. The youth forms incorrect judgments on the affairs of life. Only with maturity comes that precise co-ordination of data which is implied by a good adjustment of thoughts to things. Lastly, with the integration by which simple mental acts are combined into complex mental acts, we see the like. In the nursery you cannot obtain continuous attention—there is inability to form a coherent series of impressions; and there is a parallel inability to unite many co-existent impressions, even of the same order: witness the way in which a child's remarks on a picture show that it attends only to the individual objects represented, and never to the picture as a whole. But advancing years bring the ability to understand an involved sentence, to follow long trains of reasoning, to hold in one mental grasp numerous concurrent circumstances. A like progressive integration takes place among the mental changes we distinguish as feelings; which in a child act singly, producing impulsiveness, but in an adult act more in concert, producing a comparatively balanced conduct.

After these illustrations supplied by individual evolution, we may deal briefly with those supplied by general evolution, which are analogous to them. A creature of very low intelligence, when aware of some large object in motion near it, makes a spasmodic movement, causing, it may be, a leap or a dart. The perceptions implied are relatively simple, homogeneous, and indefinite: the moving objects are not distinguished in their kinds as injurious or otherwise, as advancing or receding. The actions of escape, too, are all of one kind, have no adjustments of direction, and may bring the creature nearer the source of peril instead of further off. At a higher stage the dart or the leap is away from danger: the nervous changes are so far specialized that there results distinc-

tion of direction; indicating a greater variety among them, a greater co-ordination or integration of them in each process, and a greater definiteness. In still higher animals, able to discriminate between enemies and not-enemies, as a bird which flies from a man but not from a cow, the acts of perception have severally become united into more complex wholes, since cognition of certain differential attributes is implied; they have also become more multiform, since each additional component impression adds to the number of possible compounds; and they have, by consequence, become more specific in their correspondences with objects—more definite. And then in animals so intelligent that they identify by sight not species only but individuals of a species, the mental changes are yet further distinguished in the same three ways. In the course of human evolution the law is equally manifested. The thoughts of the savage are nothing like so heterogeneous in their kinds as those of the civilized man, whose complex environment presents a multiplicity of new phenomena. His mental acts, too, are much less involved—he has no words for abstract ideas, and is found to be incapable of integrating the elements of such ideas. And in all but simple matters there is none of that precision in his thinking, and that grasping of many linked conceptions, which, among civilized men, leads to the exact conclusions of science.

§ 144. How in societies the movements or functions produced by the confluence of individual actions, increase in their amounts, their multiformities, their precision, and their combination, scarcely needs insisting upon after what has been pointed out in foregoing chapters. For the sake of symmetry of statement, however, a typical example or two may be set down.

At first the military activities, undifferentiated from the rest (all men in primitive societies being warriors) are relatively homogeneous, ill-combined, and indefinite: savages making a joint attack severally fight independently, in similar ways, and without order. But as societies evolve, the movements of the thousands of soldiers which replace the tens of warriors are divided and re-divided in their kinds of movements: here are gunners, there infantry, and elsewhere cavalry. Within each of the differentiated functions of these bodies there come others: there are distinct

actions of privates, sergeants, captains, colonels, generals, as also of those who constitute the commissariat and those who attend to the wounded. The clustered motions that have thus become comparatively heterogeneous in general and in detail, have simultaneously increased in precision; so that in battle, men and the regiments formed of them are made to take definite positions and perform definite acts at definite times. Once more, there has gone on that integration by which the multiform actions of an army are directed to a single end. By a co-ordinating apparatus having the commander-in-chief for its centre, the charges, and halts, and retreats are duly concerted; and a hundred thousand individual motions are united under one will.

Again on comparing the rule of a savage chief with that of a civilized government, aided by its subordinate local governments and their officers, down to the police, we see how, as men have advanced from tribes of hundreds to nations of millions, the regulative action has grown large in amount; how, guided by written laws, it has passed from vagueness and irregularity to comparative precision; and how it has subdivided into processes increasingly multiform. Or after observing how the barter that goes on among barbarians differs from our own commercial processes, by which a million's worth of commodities is distributed daily; by which the relative values of articles immensely varied in kinds and qualities are exactly measured, and the supplies adjusted to the demands; and by which industrial activities of all orders are so combined that each depends on the rest and aids the rest; we see that the kind of movement which constitutes trade, has become progressively more vast, more varied, more definite, and more integrated.

§ 145. A finished conception of Evolution thus includes the re-distribution of the retained motion, as well as that of the component matter. This added element of the conception is scarcely, if at all, less important than the other. The movements of the Solar System have a significance equal to that which the sizes, forms, and relative distances of its members possess. The Earth's geographical and geological structure are not more important elements in the order of Nature than are the motions,

regular and irregular, of the water and the air clothing it. And of the phenomena presented by an organism, it must be admitted that the combined sensible and insensible actions we call its life do not yield in interest to its structural traits. Leaving out, however, all implied reference to the way in which these two orders of facts concern us, it is clear that with each re-distribution of matter there necessarily goes a re-distribution of motion; and that the unified knowledge constituting Philosophy must comprehend both aspects of the transformation.

Our formula, therefore, needs an additional clause. To combine this satisfactorily with the clauses as they stand in the last chapter is scarcely practicable; and for convenience of expression it will be best to change their order. On doing this, and making the requisite addition, the formula finally stands thus:—*Evolution is an integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation.*

[NOTE. Only at the last moment, when this sheet is ready for press and all the rest of the volume is standing in type, so that new matter cannot be introduced without changing the "making up" throughout the following pages, have I perceived that the above formula should be slightly modified. Hence my only practicable course is to indicate here the alteration to be made, and to set forth the reasons for it in Appendix A.

The definition of Evolution needs qualifying by introduction of the word "relatively" before each of its antithetical clauses. The statement should be that "*the matter passes from a* relatively *indefinite, incoherent homogeneity to a* relatively *definite, coherent heterogeneity.* Already this qualification has been indicated in a note to § 116 (page 265), but, more effectually to exclude misapprehensions, it must be incorporated in the definition. In Appendix A are named the circumstances which led to inadequate recognition of it.]

## CHAPTER XVIII

### THE INTERPRETATION OF EVOLUTION

§ 146. Is this law ultimate or derivative? Must we rest satisfied with the conclusion that throughout all classes of concrete phenomena such is the course of transformation? Or is it possible for us to ascertain *why* such is the course of transformation? May we seek for some all-pervading principle which underlies this all-pervading process? Can the inductions set forth in the preceding four chapters be reduced to deductions?

Manifestly this community of result implies community of cause. It may be that of the cause no account can be given, further than that the Unknowable is manifested to us after this mode. Or, it may be that this mode of manifestation is implied by a simpler mode, from which these many complex effects follow. Analogy suggests the latter inference. Just as it was possible to interpret the empirical generalizations called Kepler's laws, as necessary consequences of the law of gravitation; so it may be possible to interpret the foregoing empirical generalizations as necessary consequences of some deeper law.

Unless we succeed in finding a *rationale* of this universal metamorphosis, we obviously fall short of that completely unified knowledge constituting Philosophy. As they at present stand, the several conclusions we have lately reached appear to be independent. There is no demonstrated connexion between increasing definiteness and increasing heterogeneity, or between both and increasing integration. Still less proof is there that these laws of the re-distribution of matter and motion are necessarily correlated with those laws of the direction of motion

and the rhythm of motion, previously set forth. But until we see these now separate truths to be implications of one truth, our knowledge remains imperfectly coherent.

§ 147. The task before us, then, is that of exhibiting the phenomena of Evolution in synthetic order. Setting out from an established ultimate principle, it has to be shown that the course of transformation among all kinds of existences cannot but be that which we have seen it to be. It has to be shown that the re-distribution of matter and motion, *must* everywhere take place in those ways, and produce those traits, which celestial bodies, organisms, societies, alike display. And it has to be shown that in this universality of process, is traceable the same *necessity* which we find in each simplest movement around us, down to the accelerated fall of a stone or the recurrent beat of a harp-string.

In other words, the phenomena of Evolution have to be deduced from the Persistence of Force. As before said—"to this an ultimate analysis brings us down, and on this a rational synthesis must build up." This, being the ultimate truth which transcends experience by underlying it, furnishes a common basis on which the widest generalizations stand; and hence these widest generalizations are to be unified by referring them to this common basis. Already the truths that there is equivalence among transformed forces, that motion follows the line of least resistance or greatest traction and that it is universally rhythmic, we have found to be severally deducible from the persistence of force; and this affiliation of them on the persistence of force has reduced them to a coherent whole. Here we have similarly to affiliate the universal traits of Evolution, by showing that, given the persistence of force, the re-distribution of Matter and Motion necessarily proceeds in such ways as to produce these traits. By doing this we shall unite them as correlative manifestations of one law, at the same time that we unite this law with the foregoing simpler laws.

§ 148. Before proceeding it will be well to set down some principles that must be borne in mind. In interpreting Evolution we shall have to consider, under their special forms, the various resolutions of force or energy which accompany the re-distributions

of matter and motion. Let us glance at such resolutions under their most general forms.

Any incident force is primarily divisible into its *effective* and *non-effective* portions. In mechanical impact the entire momentum of a striking body is never communicated to the body struck: even under those most favourable conditions in which the striking body loses all its sensible motion, there still remains with it some of the original momentum under the shape of that insensible motion produced among its particles by the collision. Again, of the light or heat falling on any mass, a part, more or less considerable, is reflected; and only the remaining part works molecular changes in the mass. Next it is to be noted that the effective force is itself divisible into the *temporarily effective* and the *permanently effective.* The units of an aggregate acted on may undergo only those rhythmical changes of relative position which constitute increased vibration; or they may also undergo changes of relative position which are not from instant to instant neutralized by opposite ones. Of these the first, disappearing in the shape of radiating undulations, leave the molecular arrangement as it originally was; while the second conduce to one form of that re-arrangement characterizing compound Evolution. Yet a further distinction has to be made. The permanently effective force works out changes of relative position of two kinds—the *insensible* and the *sensible.* The insensible transpositions among the units are those constituting molecular changes, including what we call chemical composition and decomposition; and it is these which largely constitute the qualitative differences that arise in an aggregate. The sensible transpositions are such as result when certain of the units—molar units as well as molecular units—instead of being put into different relations with their immediate neighbours, are carried away from them and deposited elsewhere.

Concerning these divisions and subdivisions of any force affecting an aggregate, the fact which it chiefly concerns us to observe is that they are complementary to one another. Of the whole incident force, the effective must be that which remains after deducting the non-effective. The two parts of the effective force must vary inversely as each other: where much of it is temporarily

effective, little of it can be permanently effective; and *vice versâ*. Lastly, the permanently effective force, being expended in working both the insensible re-arrangements which constitute molecular modification, and the sensible re-arrangements which result in structure, must generate of either kind an amount that is great or small in proportion as it has generated a small or great amount of the other.

## CHAPTER XIX

### THE INSTABILITY OF THE HOMOGENEOUS: EXEMPLIFYING INSTABILITY AT LARGE *

§ 149. THE difficulty of dealing with transformations so many-sided as those which all existences have undergone, or are undergoing, is such as to make a definite or complete deductive interpretation seem almost hopeless. So to grasp the total process of re-distribution, as to see simultaneously its several necessary results in their actual interdependence, is scarcely possible. There is, however, a mode of rendering the process as a whole tolerably comprehensible. Though the genesis of the re-arrangement undergone by every evolving aggregate is in itself one, it presents to our intelligence several factors; and after interpreting the effects of each separately, we may, by synthesis of the interpretations, form an adequate conception.

The proposition which comes first in logical order is that some re-arrangement must result; and this proposition may be best dealt with under the more specific shape, that the condition of homogeneity is a condition of unstable equilibrium.

First, as to the meanings of the terms, respecting which some readers may need explanation. The state of "unstable equilibrium," so named in mechanics, is well illustrated by a stick standing on its lower end, in contrast with the state of stable equilibrium of a stick suspended by its upper end: the one instantly losing its equilibrium and the other regaining it if disturbed. But the reader must be warned against confusing the instability thus exemplified with the instability here to be treated

* The idea developed in this chapter originally formed part of an article on "Transcendental Physiology," published in 1857. See *Essays*, vol. I.

of. The one shown by a stick on end may be called an external instability, while that which we have now to consider is an internal instability. It is not alleged that a homogeneous aggregate is liable because of its homogeneity to be overthrown or deranged by an external force. The allegation is that its component parts cannot maintain their arrangements unaltered: they must forthwith begin to change their relations to one another. Let us take a few illustrations.

Of mechanical ones the most familiar is that of the scales. If they be accurately made and not clogged by dirt or rust, it is impossible to keep a pair of scales perfectly balanced: eventually one scale will descend and the other ascend—they will assume a heterogeneous relation. Could a mass of water be brought into a state of perfect homogeneity—a state of complete quiescence, and exactly equal density throughout—yet the radiation of heat from neighbouring bodies, by affecting differently its different parts, would inevitably produce inequalities of density and consequent currents; and would so render it to that extent heterogeneous. Take a piece of red-hot matter, and however evenly heated it may at first be, it will quickly cease to be so: the exterior, cooling faster than the interior, will become different from it in temperature. And the lapse into heterogeneity of temperature, so obvious in this extreme case, takes place more or less in the cases of all surrounding objects, which are ever being warmed or cooled. The action of chemical forces supplies other illustrations. Expose a fragment of metal to air or water, and in course of time it will be coated with a film of oxide, carbonate, or other compound: its outer parts will become unlike its inner parts. Often the heterogeneity produced by the actions of chemical forces on the surfaces of masses is not striking, because the changed portions are soon washed away, or otherwise removed. But if this be prevented comparatively complex structures result. In some quarries of trap-rock there are striking examples. Not unfrequently a piece of trap may be found reduced, by the action of the weather, to a number of loosely-adherent coats, like those of an onion. Where the block has been undisturbed, we may trace the whole series of these, from the angular, irregular outer one, through successively included ones in which the shape becomes gradually rounded,

ending at length in a spherical nucleus. On comparing the original mass of stone with this group of concentric coats, each differing from the rest in form, and probably in the state of decomposition it has arrived at, we get a marked illustration of the multiformity to which, in lapse of time, a uniform body may be brought by external chemical action. The instability of the homogeneous is equally seen in the changes set up throughout the interior of a mass, when it consists of units that are not rigidly bound together. The molecules of a slowly-settling precipitate do not remain separate, and equably distributed through the fluid in which they make their appearance. They aggregate either into crystalline grains or into flocculi; and where the mass of fluid is great and the process prolonged, these flocculi do not continue equi-distant, but assemble into groups. That is to say, there is a destruction of the balance at first subsisting among the diffused particles, and also of the balance at first subsisting among the groups into which these particles unite.

The instability thus variously illustrated is consequent on the fact that the several parts of any homogeneous aggregate are exposed to different forces—forces which differ either in kind or amount; and are of necessity differently modified. The relations of outside and inside, and of comparative nearness of the parts to neighbouring sources of influence, imply the reception of influences that are unlike in quantity, or quality, or both: unlike changes, now temporary now permanent, being caused.

For like reasons the process must repeat itself in each of the component masses of units that are differentiated by the modifying forces. Each of these minor groups, like the major group, must gradually, in obedience to the unlike influences acting on it, lose its balance of parts, and pass from a uniform into a multiform state. And so on continuously. Whence, indeed, it follows that not only must the homogeneous lapse into the non-homogeneous, but the more homogeneous must tend ever to become less homogeneous. If any given whole, instead of being absolutely uniform throughout, consist of parts distinguishable from one another—if each of these parts, while somewhat unlike other parts, is uniform within itself; then, each of them being in unstable equilibrium, it follows that while the changes set up

within it must render it multiform, they must at the same time render the whole more multiform than before. The general principle, now to be followed out in its applications, is thus somewhat more comprehensive than the title of the chapter implies.

No demurrer to the conclusions drawn, can be based on the truth that perfect homogeneity nowhere exists; since, whether that state with which we commence be or be not one of perfect homogeneity, the process must equally be towards a relative heterogeneity.

§ 150. The stars are distributed with a three-fold irregularity. There is first the marked contrast between the Milky Way and other parts of the heavens, in respect of the quantities of stars within given visual areas. There are secondary contrasts of like kind in the Milky Way itself, which has its thick and thin places; as well as throughout the celestial spaces in general, which are more closely strewn in some regions than in others. And there is a third order of contrasts produced by the aggregation of stars into small clusters. Besides this heterogeneity in the distribution of stars, considered without distinctions of kind, a further heterogeneity is disclosed when they are classified by their differences of colour, which answer to differences of physical constitution. While yellow stars are found in all parts of the heavens, red and blue stars are not so: there are wide regions in which both red and blue stars are rare; there are regions in which the blue occur in considerable numbers, and there are other regions in which the red are comparatively abundant. Yet one more irregularity of like significance is presented by the nebulæ. These are not dispersed with anything like uniformity, but are far more numerous around the poles of the galactic circle than in the neighbourhood of its plane.

No one will expect that anything like a definite interpretation of this structure can be given on the hypothesis of Evolution, or any other hypothesis. Such an interpretation would imply some reasonable assumption respecting the pre-existing distribution of the stellar matter and of the matter forming nebulæ, and we have no warrant for any assumption. If we allow imagination to range back through antecedent possibilities and probabilities, we see it to

be unlikely that homogeneous matter filled the space which our Sidereal System now fills, at a time immediately preceding its initiation. Rather the evidence which the heavens present implies that the distribution out of which the present distribution arose was irregular in all respects. Though certain traits of our galaxy suggest that it has a vague individuality, and that, along with their special motions, its stars have some general motion; yet the evidence forces on us the conclusion that many varieties of changes have been simultaneously going on in its different parts. We find nebulæ in all stages of concentration, star-clusters variously condensed, groups of larger stars approximating in different degrees, as well as regions like those which the nubeculæ occupy, presenting complex structures and apparently active changes. The most which can be said respecting this total distribution is that, subject as all parts of our Sidereal System are to the law of gravitation, the heterogeneities it exhibits, everywhere implying a progressing concentration, that is, integration, point backward to a less heterogeneous state and point forward to a more heterogeneous state. But, leaving aside this too transcendent question, we may without undue rashness consider from the evolution point of view the changes to be anticipated in one of those collections of matter described as a diffused nebulosity, or one of those more distinct ones of which the outlying parts are compared to wisps of cloud blown about by the wind. The only evolutional process which can at first be displayed is the primary one of integration—the gathering together through mutual attraction of the parts; for in this early stage in which indefiniteness and incoherence are so fully exemplified, there does not yet exist such an aggregate as is capable of exhibiting secondary re-distributions: we have only the dispersed components of such an aggregate. Contemplating, then, only the process of integration, we may, without asking anything about the previous history of an irregular nebula, safely assume that its parts have their respective proper motions; for the chances are infinity to one against a state of rest relatively to one another. Further, the chances are infinity to one against their proper motions being such that during concentration they will cancel one another: the motion of some part, or the resultant of the motions of several parts, will constitute a proper motion distinct from that which

mutual gravitation generates—a motion which, unless just counterbalanced by an opposite one (again an infinite improbability) will generate rotation. It may, indeed, be argued that, apart from any pre-existing proper motions of its parts, a nebulous mass, if irregular, will acquire rotation while integrating; since each outlying fragment, arriving after the rest have been gathered together, is infinitely unlikely to fall into the mass in such a manner that its motion will be entirely cancelled by resistance; but, falling into it so as to be deflected laterally, will have its motion of approach so changed in direction as to become in part a motion of revolution: a resultant of all such motions, largely conflicting, being an eventual rotation of the mass. It must not, however, be assumed that this will necessarily be the rotation of a solitary aggregate. The great nebula in *Andromeda* does not appear on the way to form a single body; and that in *Canes Venatici* is an advanced spiral of which the outer parts have a tangential motion too great to permit of their being drawn into the centre. Rather the apparent implication of the structure is that there will be formed a cluster of masses revolving round a common centre of gravity. Such cases, joined with those of the annular nebulæ, suggest that often the processes of integration result in compound structures, various in their kinds, while in other cases, and perhaps most frequently, single masses of rotating nebulous matter are formed.

Ignoring all such possibilities and probabilities, however, and limiting our attention to that form of the nebular hypothesis which regards the solar system as having resulted from a rotating spheroid of diffused substance; let us consider what consequence the instability of the homogeneous necessitates. Being oblate in figure, unlike in the densities of its centre and surface, unlike in their temperatures, and probably unlike in the angular velocities of its parts, such a mass cannot be called homogeneous; and any further changes exhibited by it can illustrate the general law only as being changes from a more homogeneous to a less homogeneous state. Just noting that one of these changes is the increasing oblateness of form, let us go on to observe those which are to be found in the transformations of such of its parts as are at first homogeneous within themselves. If we accept the conclusion that the equatorial portion of this rotating and contracting spheroid will, at successive

stages, have a centrifugal force great enough to prevent nearer approach to the centre of rotation, and will so be left behind; we shall find, in the fate of the detached ring, an exemplification of the principle we are following out. Consisting of gaseous matter, such a ring, even if uniform at the time of its detachment, could not continue so. In the absence of equality among the forces, internal and external, acting on it, there must be a point or points at which the cohesion of its parts would be less than elsewhere—a point or points at which rupture would therefore take place. The original assumption was that the ring would rupture at one place only, and would then collapse on itself. But this was a more than questionable assumption: such, at least, I know to have been the opinion of the late Sir John Herschel. So vast a ring, consisting of matter having such feeble cohesion, must break up into many parts. Nevertheless, appeal to another high authority—the late Sir G. B. Airy—yielded verification for the belief that the ultimate result which Laplace predicted would take place. And here is furnished a further illustration of the instability of the homogeneous. For even supposing the masses of nebulous matter into which such a ring separated, were so much alike in their sizes and distances as to attract one another with exactly equal forces (which is infinitely improbable); yet the unequal actions of external disturbing forces would inevitably destroy their equilibrium—there would be one or more points at which adjacent masses would begin to part company. Separation, once commenced, would with accelerating speed lead to a grouping of the masses. A like result would eventually take place with the groups thus formed; until they at length aggregated into a single mass.

§ 151. Already so many references have been made to the formation of a crust over the originally incandescent Earth, that it may be thought superfluous again to name it. It has not, however, been thus far considered in connexion with the general principle under discussion. Here it must be noted as a necessary consequence of the instability of the homogeneous. In this cooling and solidification of the Earth's surface, we have one of the simplest, as well as one of the most important, instances of that change from a uniform to a multiform state which occurs in any mass through

exposure of its component parts to unlike conditions. To the differentiation of the Earth's exterior from its interior, thus brought about, we must add one of the most conspicuous differentiations which the exterior itself afterwards undergoes, as being similarly brought about. Were the forces to which the surface of the Earth is subject alike in all directions, there would be no reason why certain of its parts should become permanently unlike the rest. But being unequally exposed to the chief external centre of force—the Sun—its main divisions become unequally modified. While the crust thickens and cools, there arises that contrast, now so decided, between the polar and equatorial regions.

Along with these most marked physical differentiations of the Earth, there have been going on numerous chemical differentiations, admitting of similar interpretation. Leaving aside all speculations concerning the origin of the so-called simple substances, it will suffice to show how, in place of that comparative homogeneity of the Earth's crust, chemically considered, which must have existed when its temperature was high, there has arisen, during its cooling, an increasing chemical heterogeneity. Let us contemplate this change somewhat in detail. At an extreme heat the bodies we call elements cannot combine. Even under such heat as can be generated artificially some very strong affinities yield; and the great majority of chemical compounds are decomposed at much lower temperatures. Probably, therefore, when the Earth was in its first state of incandescence, there were no chemical combinations. But without drawing this inference, let us set out with the unquestionable fact that the compounds which can exist at the highest temperatures, and which must therefore have been the first formed as the Earth cooled, are those of the simplest constitutions. The protoxides (including under that head the alkalies, earths, &c.) are, as a class, the most stable compounds known—the least changeable by heat. These, consisting severally of one atom of each component element, are but one degree less homogeneous than the elements themselves. More heterogeneous than these, more decomposable by heat, and therefore later in the Earth's history, are the deutoxides, tritoxides, peroxides, &c.; in which two, three, four, or more atoms of oxygen are united with one atom of metal or other base. Still less able to resist heat are the salts, which present us

with compound atoms each made up of five, six, seven, eight, ten, twelve, or more atoms, of three or more kinds. Then there are the hydrated salts of a yet greater heterogeneity, which undergo partial decomposition at much lower temperatures. After them come the further-complicated supersalts and double salts, having a stability again decreased; and so throughout. After making a few unimportant qualifications demanded by peculiar affinities, it may be asserted as a general law of these inorganic combinations that, other things equal, the stability decreases as the complexity increases. When we pass to the compounds which make up organic bodies, we find this general law further exemplified: we find much greater complexity and much less stability. A molecule of albumen, for instance, consists of more than two hundred ultimate units of five different kinds. According to the latest analyses it contains in each molecule, 72 of carbon, 18 of nitrogen, 1 of sulphur, 112 of hydrogen, and 22 of oxygen—in all, 225 atoms; or, more strictly speaking, equivalents. And this substance is so unstable as to decompose at quite moderate temperatures; as that to which the outside of a joint of roasting meat is exposed. Possibly it will be objected that some inorganic compounds, as phosphuretted hydrogen, chloride of nitrogen, and the nitrogen-explosives in general, are more decomposable than most organic compounds. This is true. But the admission may be made without damage to the argument. The proposition is not that *all* simple combinations are more stable than *all* complex ones. To establish our inference it is necessary only to show that, as an *average fact*, the simple combinations can exist at a higher temperature than the complex ones. And this is beyond question. Thus it is manifest that the present chemical heterogeneity of the Earth's surface, and of the bodies upon it, has arisen by degrees as the decrease of heat has permitted; and that it has shown itself in three forms:—first, in the multiplication of chemical compounds; second, in the greater number of different elements contained in the more modern of these compounds; and third, in the higher and more varied multiples in which these more numerous elements combine.

Without specifying them, it will suffice just to name the meteorologic processes eventually set up in the Earth's atmosphere,

as further illustrating the alleged law. They equally display that destruction of a homogeneous state which results from unequal exposure to incident forces.

§ 152. Take a mass of unorganized but organizable matter—either the body of one of the lowest living forms, or the germ of one of the higher: both comparatively homogeneous. Consider its circumstances. Either it is immersed in water or air or is contained within a parent organism. Wherever placed, however, its outer and inner parts stand differently related to surrounding agencies—nutriment, oxygen, and the various stimuli. But this is not all. Whether it lies quiescent at the bottom of a pool or on the leaf of a plant; whether it moves through the water preserving some definite attitude; or whether it is in the inside of an adult; it equally happens that certain parts of its surface are more exposed to surrounding agencies than other parts—in some cases more exposed to light, heat, or oxygen, and in other cases to the maternal tissues and their contents. Hence must follow the loss of its original equilibrium. This may take place in one of two ways. Either the disturbing forces may be such as to over-balance the affinities of the organic elements, and there results decomposition; or, as ordinarily occurs, such changes are induced as do not destroy the organic compounds but only modify them: the parts most exposed to the modifying forces being most modified. To elucidate this a few cases are required.

Observe first what appear to be exceptions. Certain minute animal forms present either no appreciable differentiations or differentiations so obscure as to be made out with great difficulty. Concerning these forms, however, note the fact that in all cases (some say in *nearly* all) the presence of a nucleus shows conformity to the general law, since it implies a contrast between the innermost protoplasm and the protoplasm surrounding it. But let us pass on to the seemingly exceptional fact that the surrounding protoplasm does not exhibit the kind of differentiation between inner and outer above alleged. To this objection, there immediately presents itself the answer that this homogeneous body-substance does not become heterogeneous because its parts are not subject to any permanent heterogeneity of conditions: it has no

fixed surface. In all members of the lowest group, *Proteomyxa*, the protoplasm continually protrudes itself, now in thicker now in thinner processes—pseudopodia; proved to have no limiting membranes by often coalescing. These, when they touch fragments of nutriment, contract and draw them into the mass of the body: so that what was just before external now becomes internal. Thus there are no fixed relations of parts and therefore no differentiations. And it is noteworthy that in certain of the *Amœbæ*, less excursive than others of the type in the movements of their substance, we see an incipient differentiation: sometimes there is an investing film, "delicate and evanescent," implying that an outer part, which is for a short time stationary, begins to be differentiated. Perceiving, then, that this apparent exception is in fact a verification, we go on to observe that permanent relations of inner and outer are followed by permanent differentiations. Elsewhere (*Essays*, i, 439) I have quoted from Sachs various proofs that a portion of protoplasm, whether normally detached, as in a spore, or abnormally detached, as by a rupture, forthwith becoming globular, at once acquires a surface denser than the interior; and Kerner similarly describes the protoplasm of a zoospore as "fixing itself and putting on a delicate cell-wall." These cases, joined with those of various *Protozoa* which, ceasing their active changes of form, pass into a resting stage and become enclosed in a cyst, and joined with the cases of *Protophyta*, like *Sphærella nivalis* or "Red Snow," which, in its young stage ovoid, flagellate, locomotive, and secreting a skin, presently passes into a resting stage and becomes spherical and covered by a substantial cell-membrane, yield clear evidence that in these lowest types there is a lapse from a more homogeneous state into a less homogeneous state. And throughout the higher *Protozoa* and *Protophyta*, the primary contrast is between cell-membrane and cell-contents—between the part exposed to environing forces and the part sheltered from them.

The transition—the most important transition which the organic world presents—between the simple forms above exemplified and those compound forms in which a number of such are united into a colony, is well seen in certain minute algæ, *Pandorina* and *Eudorina*: each being a spherically-arranged colony of sixteen or

thirty-two members. In this first advance from unicellular types to multicellular types we find conformity to the general law in so far that the hollow sphere conspicuously displays the primary contrast between outer and inner: a primitive amorphous cluster has undergone a marked differentiation of parts corresponding to the difference of conditions. Still more instructive is the evidence furnished by types slightly in advance of these—*Pleodorina* and *Volvox*; the first consisting of some 128 cells and the second of 10,000 or more. Hollow spheres like the foregoing, they present in common the significant trait that, revolving, as they do, on a constant axis and moving forward approximately in the line of that axis, their two ends are exposed to slightly different conditions, and the primitive homogeneity of the members of the colony has, in consequence, lapsed into an appropriate heterogeneity. These ciliated alga-cells, whether living singly or joined into groups, severally have a minute red speck which is proved to be sensitive to light, and causes motion towards it. Now in these compound forms just named, the eye-spots are more developed in those cells forming the anterior part of the spherical colony—cells which also carry on more actively the nutritive function; while those cells which form the posterior part of the sphere, and carry on the reproductive function, have smaller eye-spots. On passing to the animal kingdom (which at its root is so little differentiated from the vegetal kingdom that there are unsettled disputes respecting the inclusion of the lowest forms in the one or the other) we meet with parallel illustrations. The nucleated cell, which is the common starting point for all organisms, animal and vegetal, presents us as before with the primary contrast between inner and outer. And as in the multi-cellular plants so in the multi-cellular animals, a like primary contrast is forthwith repeated in the initial clusters of cells. Produced by the repeated fissions of the primitive germ-cell, each such cluster presently forms itself into a hollow sphere: the "cleavage cavity" being manifestly homologous with the cavity of the *Volvox*-sphere.* In simple types of *Metazoa*, as

* I may remark in passing that in the one case (and possibly by inheritance in the other) this formation of a hollow sphere is the result of the more rapid growth of the outer parts than the inner parts of a solid group. Being dependent for nutrition on light and carbon-dioxide in the water, the outside

the hydroid polyps, the *blastula* being thus established in conformity with the primary contrast of conditions, there presently begins a secondary differentiation which, like that we have seen in the *Volvox* but in a more pronounced manner, answers to the secondary contrast of conditions; for this spherical assemblage of cells becomes ovoid, and by the aid of its cilia moves through the water broad end foremost: the lapse from homogeneity of form being in some cases made more pronounced by the assumption of a sausage-shape. Simultaneously the component cells of the two ends become unlike in character. A far more marked differentiation, or lapse into greater heterogeneity, is seen when this single-layered spheroid of ciliated cells is changed into a double-layered spheroid by introversion of one side: a sack with the mouth sewn up and the bottom thrust in as far as it will go, serving to illustrate the relations of parts. Hence results the *gastrula* with its ectoderm and endoderm; severally playing contrasted parts in subsequent development. So that at successive stages there is repeated this rise of a contrast of structures answering to a contrast of conditions—that which occurs in the simple cell, that which occurs in the hollow sphere of such cells, and that which occurs in the double-walled sphere.

Illustrations presenting the law under another aspect—one from each organic kingdom—are instructive. The ciliated germ or *planula* of a Zoophyte which, during its locomotive stage, is distinguishable only into outer and inner tissues, no sooner becomes fixed than its upper end begins to assume a different structure from its lower. The disc-shaped *gemmæ* of the *Marchantia*, originally alike on both surfaces, and falling at random with

components of a *Volvox* (either the cells or the chlorophyll in each cell) have a great advantage over the cells or portions of cells which are more centrally placed; and it needs but to consider what happens if the periphery of a sphere increases at a proportionately greater rate than its contents to see that it must either leave the contents behind or draw them after it and become hollow. An analogous effect of excessive peripheral growth may occasionally be seen exemplified when, after a dry fit during which potatoes have not grown much, there comes rain and a rapid increase of bulk: this being the explanation of the fact that in very large potatoes there is not uncommonly a split in the interior, caused by the strain which the disproportionate growth of the periphery necessarily causes.

either side uppermost, immediately begin to develop rootlets on their under sides and *stomata* on their upper sides: a fact proving beyond question, that this primary differentiation is determined by this fundamental contrast of conditions.

Of course in the germs of higher organisms, the metamorphoses immediately due to the instability of the homogeneous, are soon masked by those due to the assumption of the hereditary type. Even in the early stages above described there are to be traced modifications thus originating. Even before the primary cell-multiplication begins, there is said to be an observable distinction between the two poles of the egg-cell, foreshadowing the different germ-layers. Of course as development progresses assumption of the transmitted type of structure quickly obscures these primary lapses from homogeneity; though for some time the fundamental relations of inner and outer are recognizable in the differentiations. But what has been said suffices to establish the alleged general truth. It is enough that incipient organisms, setting out from relatively homogeneous arrangements, forthwith begin to fall into relatively heterogeneous ones. It is enough that the most conspicuous differentiations which they display, correspond to the most marked differences of conditions to which their parts are subject. It is enough that the habitual contrast between outside and inside, which we *know* is produced in inorganic masses by unlikeness of exposure to incident forces, is paralleled by the first contrast which makes its appearance in all organic masses.

It remains to point out that in the assemblage of organisms constituting a species, the principle enunciated is no less traceable. We have abundant materials for the induction that each species will not remain uniform—is ever becoming to some extent multiform; and there is ground for the deduction that this lapse from homogeneity to heterogeneity is caused by the subjection of its members to unlike circumstances. Tending ever to spread from its original habitat into adjacent habitats, each species must have its peripheral parts subject to sets of forces unlike those to which its central parts are subject, and so must tend to have its peripheral members made different from its central members.

§ 153. Among mental phenomena full establishment of the

alleged law would involve an analysis too extensive for the occasion. To show satisfactorily how states of consciousness, relatively homogeneous, become heterogeneous through differences in the changes wrought by different external forces, would require us to trace out the organization of early experiences. Without here attempting this it must suffice to set down the conclusions to be drawn.

The development of intelligence is, under one of its chief aspects, a classifying of the unlike things previously confounded together—a formation of sub-classes and sub-sub-classes, until the once confused aggregate of objects known, is resolved into an aggregate which unites great heterogeneity among its multiplied groups, with complete homogeneity among the members of each group. On following, through ascending grades of creatures, the genesis of that vast structure of knowledge acquired by sight, we see that in the first stage, where eye-specks suffice only for discriminating light from darkness, there can be no classifications of objects seen, save those based on the manner in which light is obstructed, and the degree in which it is obstructed. By such undeveloped visual organs, the shadows perceived would be merely distinguished into those of the stationary objects which the creature passed during its own movements, and those of the moving objects which came near while it was at rest; so that the extremely general classification of visible things into stationary and moving, would be the earliest formed. A kindred step follows. While the simplest eyes cannot distinguish between an obstruction of light caused by a small object close to, and an obstruction caused by a large object at some distance, eyes a little more developed can distinguish them; whence must result a vague differentiation of the class of moving objects into the nearer and the more remote. Further developments which make possible a better estimation of distances by adjustment of the optic axes, and those which, through enlargement and subdivision of the retina, make possible the discrimination of shapes, must give greater definiteness to the classes already formed, and subdivide these into smaller classes, consisting of objects less unlike. In every infant may be traced the analogous transformation of a confused aggregate of impressions of surrounding things, not recognized as differing in

their distances, sizes, and shapes, into separate classes of things unlike one another in these and various other respects. And in both cases the change from this first indefinite, incoherent and comparatively homogeneous consciousness, to a definite, coherent, and heterogeneous one, is due to differences in the actions of incident forces on the organism. These brief indications must suffice. Probably they will give adequate clue to an argument by which each reader may satisfy himself that the course of mental evolution offers no exception to the general law. In further aid of such an argument, I will here add an illustration which is comprehensible apart from the process of mental evolution as a whole.

It has been remarked (I am told by Coleridge) that with the advance of language, words which were originally alike in their meanings acquire unlike meanings—a change he expressed by the formidable word "desynonymization." Among indigenous words this loss of equivalence cannot be clearly shown; because in them the divergences of meaning began before the dawn of literature. But among words that have been coined, or adopted from other languages, since the writing of books commenced, it is demonstrable. By the old divines, *miscreant* was used in its etymological sense of *unbeliever;* but in modern speech it has entirely lost this sense. Similarly with *evil-doer* and *malefactor.* Exactly synonymous as these are by derivation, they are no longer synonymous by usage. By a *malefactor* we now understand a convicted criminal, which is far from being the acceptation of *evil-doer.* The verb *produce* bears in Euclid its primary meaning—to *prolong* or *draw out;* but the now largely-developed meanings of *produce*, have little in common with the meanings of *prolong*, or *draw out.* In the Church of England liturgy an odd effect now results from the occurrence of *prevent* in its original sense—*to come before*, instead of its modern specialized sense—*to come before with the effect of arresting.* But the most conclusive cases are those in which the contrasted words consist of the same parts differently combined, as in *go under* and *undergo.* We *go under* a tree, and we *undergo* a pain. But though, if analytically considered, the meanings of these expressions would be the same were the words transposed, habit has so far modified their meanings that we could not without absurdity

speak of *undergoing* a tree and *going under* a pain. Many such instances show that between two words which are originally of like force, an equilibrium cannot be maintained. Unless they are daily used in exactly equal degrees, in exactly similar relations (which is infinitely improbable), there necessarily arises a habit of associating one rather than the other with particular acts, or objects. Such a habit once commenced, becomes confirmed; and gradually their homogeneity of meaning disappears.

Should any difficulty be felt in understanding how these mental changes exemplify a law of physical transformations that are wrought by physical forces, it will disappear on contemplating acts of mind as nervous functions. It will be seen that each loss of equilibrium above instanced, is a loss of functional equality between some two elements of the nervous system. And it will be seen that, as in other cases, this loss of functional equality is due to differences in the incidence of forces.

§ 154. Masses of men, in common with all other masses, show a like proclivity similarly caused. Small combinations and large societies equally manifest it; and in the one, as in the other, both governmental and industrial differentiations are initiated by it. Let us glance at the facts under these heads.

A business-partnership, balanced as the authorities of its members may theoretically be, presently becomes a union in which the authority of one partner is tacitly recognized as greater than that of the other or others. Though the shareholders have given equal powers to the directors of their company, inequalities of power soon arise among them; and often the supremacy of some one director grows so marked, that his decisions determine the course which the board takes. Nor in associations for political, charitable, literary, or other purposes, do we fail to find a like process of division into dominant and subordinate parties; each having its leader, its members of less influence, and its mass of uninfluential members. These minor instances in which unorganized groups of men, standing in homogeneous relations, may be watched gradually passing into organized groups of men standing in heterogeneous relations, give us the key to social inequalities. Barbarous and civilized communities are alike characterized by separation into

classes, as well as by separation of each class into more important and less important units; and this structure is the gradually-consolidated result of a process like that daily exemplified in trading and other combinations. So long as men are constituted to act on one another, either by physical force or by force of character, the struggles for supremacy must finally be decided in favour of some class or some one; and the difference once commenced must tend to become ever more marked. Its unstable equilibrium being destroyed, the uniform must gravitate with increasing rapidity into the multiform. And so supremacy and subordination must establish themselves, as we see they do, throughout the whole structure of a society, from the great class-divisions pervading its entire body, down to village cliques, and even down to every posse of school-boys. Probably it will be objected that such changes result, not from the homogeneity of the original aggregations, but from their non-homogeneity—from certain slight differences existing among their units at the outset. This is doubtless the proximate cause. In strictness, such changes must be regarded as transformations of the relatively homogeneous into the relatively heterogeneous. But an aggregation of men absolutely alike in their endowments would eventually undergo a similar transformation. For in the absence of uniformity in the lives severally led by them—in their occupations, physical conditions, domestic relations, and trains of thought and feeling—there must arise differences among them; and these must eventually initiate social differentiations. Even inequalities of health caused by accidents will, by entailing inequalities of physical and mental power, disturb the exact balance of mutual influences among the units; and the balance once disturbed will inevitably be lost.

Turning to the industrial organization, and noting that its division into regulative and operative is primarily determined, like the preceding, by differences of power (women and slaves being the first working classes); admitting, too, that even among savages some small specializations arise from individual aptitudes; we go on to observe that the large industrial divisions into which societies gravitate are due to unlikenesses of external circumstances. Such divisions are absent until such unlikenesses are established. Nomadic

tribes do not permanently expose any groups of their members to special local conditions; nor does a stationary tribe, when occupying only a small area, maintain from generation to generation marked contrasts in the local conditions of its members; and in such tribes there are no decided economic differentiations. But a community which, by conquest or otherwise, has overspread a large tract, and has become so far settled that its members live and die in their respective districts, keeps its several sections in different circumstances; and then they no longer remain alike in their occupations. Those who live dispersed continue to hunt or cultivate the earth; those who spread to the sea-shore fall into maritime occupations; while the inhabitants of some spot chosen, perhaps for its centrality, as one of periodic assemblage, become traders, and a town springs up. In the adaptations of these social units to their respective functions, we see a progress from uniformity to multiformity caused by unlike incidence of forces. Later in the process of social evolution these local adaptations are greatly multiplied. Differences in soil and climate, cause the rural inhabitants in different parts of the kingdom to have their occupations partially specialized, and to become known as chiefly producing cattle, or sheep, or wheat, or oats, or hops, or fruit. People living where coal fields are discovered are transformed into colliers; Cornishmen take to mining because Cornwall is metalliferous; and iron manufacture is the dominant industry where iron-stone is plentiful. Liverpool has taken to importing cotton, because of its proximity to the district where cotton goods are made; and for analogous reasons Hull has become the chief port at which foreign wools are brought in. Thus in general and in detail, industrial heterogeneities of the social organism primarily depend on local influences. Those divisions of labour which, under another aspect, were interpreted as due to the setting up of motion in the directions of least resistance (§ 80), are here interpreted as due to differences in the incident forces; and the two interpretations are quite consistent with each other. For that which in each case *determines* the direction of least resistance is the distribution of the forces to be overcome; and hence unlikenesses of distribution in separate localities entails unlikenesses in the lines of human actions in those localities—entails industrial differentiations.

§ 155. It has still to be shown that this general truth is demonstrable *a priori*—that the instability of the homogeneous is a corollary from the persistence of force. Already this has been tacitly implied, but here it will be proper to expand the tacit implication into definite proof.

On striking a mass of matter with such force as either to indent it or make it fly to pieces, we see both that the blow affects differently its different parts, and that the differences are consequent on the unlike relations of its parts to the force impressed. The part struck is driven in towards the centre of the mass. It thus compresses, and tends to displace, the more centrally situated portions. These, however, cannot be compressed or thrust out of their places without pressing on surrounding portions. And when the blow is violent enough to fracture the mass, we see, in the radial dispersion of the fragments, that the original momentum has been divided into numerous minor momenta, unlike in their directions. We see that the parts are differently affected by the disruptive force, because they are differently related to it in their directions and attachments—that the effects being the joint products of the force and the conditions, cannot be alike in parts which are differently conditioned. A body on which radiant heat is falling, exemplifies this truth still more clearly. Take the simplest case—that of a sphere. While the part nearest to the radiating centre receives the rays at right angles, the rays strike the other parts of the exposed side at all angles from 90° down to 0°. The molecular vibrations, propagated through the mass from the surface which receives the heat, proceed inwards at angles differing for each point. Further, the interior parts reached by the vibrations proceeding from all points of the heated side must be dissimilarly affected in proportion as their positions are dissimilar. So that whether they be on the recipient area, in the middle, or at the remote side, the constituent molecules are thrown into states of vibration more or less unlike one another.

But now, what is the ultimate meaning of the conclusion that a force produces different changes throughout a uniform mass, because the parts of the mass stand in different relations to the force Fully to understand this, we must contemplate each part as simultaneously subject to other forces—those of gravitation, of cohesion,

of molecular motion, &c. The effect wrought by an additional force, must be a resultant of it and the forces already in action. If the forces already in action on two parts of any aggregate are different in their resultant directions, the effects produced on these two parts by equal additional forces must be different in their directions. Why must they be different? Because such unlikeness as exists between the two sets of factors is made by the presence in the one of some specially-directed force that is not present in the other; and that this force will produce an effect, rendering the total result in the one case unlike that in the other, is a necessary corollary from the persistence of force. Still more manifest does it become that the dissimilarly-placed parts of any aggregate must be dissimilarly modified by an incident force, when we remember that the *quantities* of the incident force to which they are severally subject, are not equal, as above supposed, but are nearly always unequal. Look again at the above examples. The amounts of any external radiant force, which the different parts of an aggregate receive, are widely contrasted: we have the contrast between the quantity falling on the side next the radiating centre, and the quantity, or rather no quantity, falling on the opposite side; we have contrasts in the quantities received by differently-placed areas on the exposed side; and we have endless contrasts between the quantities received by the various parts of the interior. Similarly when mechanical force is expended on any aggregate, either by collision, continued pressure, or tension, the amounts of strain distributed throughout the mass are manifestly unlike for unlike positions. And it is obvious that ordinary chemical action affects surface more than centre, and often one part of the surface more than another. But to say the different parts of an aggregate receive different quantities of any force capable of changing them, is to say that if they were before homogeneous they must be rendered to a proportionate extent heterogeneous; since, force being persistent, the different quantities of it falling on the different parts, must work in them different quantities of effect—different changes. Yet one more kindred deduction is required to complete the argument. Even apart from the action of any external force, the equilibrium of a homogeneous aggregate must be destroyed by the unequal actions of its parts on one another. That mutual

influence which produces aggregation (not to mention other mutual influences) must work different effects on the different parts; since they are severally exposed to it in unlike amounts and directions. This will be clearly seen on remembering that the portions of which the whole is made up may be severally regarded as minor wholes; that on each of these minor wholes the action of the entire aggregate then becomes an external incident force; that such external incident force must, as above shown, work unlike changes in the parts of any such minor whole; and that if the minor wholes are severally thus rendered heterogeneous, the entire aggregate is rendered heterogeneous.

The instability of the homogeneous is thus deducible from that primordial truth which underlies our intelligence. One stable homogeneity only is hypothetically possible. If centres of force, absolutely uniform in their powers, were diffused with absolute uniformity through unlimited space, they would remain in equilibrium. This however, though a verbally intelligible supposition, is one that cannot be represented in thought; since unlimited space is inconceivable. But all finite forms of the homogeneous—all forms of it which we can know or conceive, must inevitably lapse into heterogeneity; and the less heterogeneous must lapse into the more heterogeneous. In three several ways does the persistence of force necessitate this. Setting external agencies aside, each unit of a homogeneous whole must be differently affected from any of the rest by the aggregate action of the rest upon it. The resultant force exercised by the aggregate on each unit, being in no two cases alike in both amount and direction, and usually not in either, any incident force, even if uniform in amount and direction, cannot produce like effects on the units. And as the various positions of the parts in relation to any incident force prevent them from receiving it in uniform amounts and directions, a further difference in the effects wrought on them inevitably arises.

One further remark is needed. The conclusion that the changes with which Evolution *commences*, are thus necessitated, has to be supplemented by the conclusion that these changes must *continue*. The absolutely homogeneous (supposing it to exist) must lose its equilibrium; and the relatively homogeneous must lapse into the relatively less homogeneous. That which is true of any total mass,

is true of the parts into which it segregates. The uniformity of each such part must as inevitably be lost in multiformity, as was that of the original whole; and for like reasons. And thus the continued changes characterizing Evolution, in so far as they are constituted by the lapse of the homogeneous into the heterogeneous, and of the less heterogeneous into the more heterogeneous, are necessary consequences of the persistence of force.

[A small change in the definition of Evolution indicated in a note at the end of Chapter XVII of this part, must be recalled as involving a correlative change in this chapter. Here, as before, the required change, though already implied (page 329), has not been sufficiently emphasized, and lack of the emphasis invites misinterpretation. For reasons like those before given, the requisite explanations cannot be made in this place. The reader will find them in Appendix A.

Replies to certain criticisms on the general doctrine set forth in this chapter will be found in Appendix C.]

## CHAPTER XX

### THE MULTIPLICATION OF EFFECTS

§ 156. To the cause of increasing complexity set forth in the last chapter, we have in this chapter to add another. Though secondary in order of time, it is scarcely secondary in order of importance. Even in the absence of the cause already assigned, it would necessitate a change from the homogeneous to the heterogeneous; and joined with it, it makes this change both more rapid and more involved. To come in sight of it we have but to pursue a step further that conflict between force and matter already delineated. Let us do this.

As already shown, when the components of a uniform aggregate are subject to a uniform force, they, being differently conditioned, are differently modified. But while we have contemplated the various parts of the aggregate as undergoing unlike changes, we have not yet contemplated the unlike changes simultaneously produced on the various parts of the incident force. These must be as numerous as the others. In differentiating the parts on which it falls in unlike ways, the incident force must itself be correspondingly differentiated. Instead of being as before, a uniform force, it must thereafter be a multiform force—a group of dissimilar forces. A few illustrations will make this truth manifest.

In the case, lately cited, of a body shattered by violent collision, besides the change of the homogeneous mass into a heterogeneous group of scattered fragments, there is a change of the homogeneous momentum into a group of momenta, heterogeneous in both amounts and directions. Similarly with the forces we know as light and heat. After the dispersion of these by a radiating body towards all points, they are re-dispersed towards all points by the

bodies on which they fall. Of the Sun's rays, issuing from him on every side, some few strike the Moon. Reflected at all angles from the Moon's surface, some few of these strike the Earth. By a like process the few which reach the Earth are again diffused: some into space, some from object to object. And on each occasion, such portions of the rays as are transmitted instead of reflected, undergo refractions or other changes which equally destroy their uniformity. More than this is true. By conflict with matter a uniform force is in part changed into forces differing in their directions, and is in part changed into forces differing in their kinds. When one body is struck against another, that which we usually regard as the effect, is a change of position or motion in one or both bodies. But this is a very incomplete view of the matter. Besides the visible mechanical result, sound is produced—a vibration in one or both bodies and in the surrounding air; and under some circumstances we call this the effect. Moreover, the air has not simply been made to vibrate; it has had currents raised in it by the transit of the bodies. Further, if there is not that great structural change which we call fracture, there is a disarrangement of the particles of the two bodies around their point of collision; amounting in some cases to a visible condensation. Yet more, this condensation is accompanied by genesis of heat. In some cases a spark—that is, light—results from the incandescence of a portion struck off. Thus by the original mechanical force expended in the collision, at least five kinds of forces have been produced. Take, again, the lighting of a candle. Primarily, this is a chemical change consequent on a rise of temperature. The process of combination having once been set going by extraneous heat, there is a continued formation of carbon dioxide, water, &c. Along with this process of combination there is a production of heat; there is a production of light; there is an ascending column of hot gases generated; there are currents caused in the surrounding air. Nor does the decomposition of one force into many forces end here. Each of the several changes worked becomes the parent of further changes. The carbon dioxide formed will eventually combine with some base; or under the influence of sunshine give up its carbon to the leaf of a plant. The water will modify the hygrometric state of the air around;

or, if the current of hot gases containing it comes against a cold body, will be condensed: altering the temperature, and perhaps the chemical state, of the surface it covers. The heat given out melts the subjacent tallow and expands whatever else it warms. The light, falling on various substances, calls forth from them reactions by which it is decomposed, and divers colours are thus produced. Similarly with these secondary actions, which may be traced out into ever-multiplying ramifications, until they become too minute to be appreciated. Universally, then, the effect is more complex than the cause. Whether the aggregate on which it falls be homogeneous or otherwise, an incident force is transformed by the conflict into a number of forces that differ in their amounts, or directions, or kinds; or in all these respects. And of this group of variously-modified forces, each ultimately undergoes a like transformation.

Let us now mark how the process of evolution is furthered by this multiplication of effects. An incident force decomposed by the reactions of a body into a group of unlike forces, becomes the cause of a secondary increase of multiformity in the body which decomposes it. By the reactions of the various parts, differently modified as we have seen they must be, the incident force itself must be divided into differently modified parts. Each differentiated division of the aggregate thus becomes a centre from which a differentiated division of the original force is again diffused. And since unlike forces must produce unlike results, each of these differentiated forces must produce, throughout the aggregate, a further series of differentiations. This secondary cause of the change from homogeneity to heterogeneity obviously becomes more potent in proportion as the heterogeneity increases. When the parts into which any evolving whole has segregated itself, have diverged widely in nature, they will necessarily react very diversely on any incident force—they will divide an incident force into so many strongly contrasted groups of forces. And each of them becoming the centre of a quite distinct set of influences must add to the number of distinct secondary changes wrought throughout the aggregate. Yet another corollary must be added. The number of unlike parts of which an aggregate consists, is an important factor in the process. Every additional specialized

division is an additional centre of specialized forces, and must be a further source of complication among the forces at work throughout the mass—a further source of heterogeneity. The multiplication of effects must proceed in geometrical progression.

§ 157. The scattered parts of an irregular nebula in course of being drawn together, or integrated, cannot display in a definite manner the secondary traits of evolution: these presuppose an aggregate already formed. We can say only that the half-independent components, each attracted by all and all by each, exhibit in their various momenta, different in their amounts and directions, a multiplication of effects produced by a single gravitative force.

But assuming that the integrative process has at length generated a single mass of nebulous matter, then the simultaneous condensation and rotation show us how two effects of the aggregative force, at first but slightly divergent, become at last widely differentiated. An increase of oblateness in this spheroid must take place through the joint action of these two forces, as the bulk diminishes and the rotation grows more rapid; and this we may set down as a third effect. The genesis of heat, accompanying augmentation of density, is a consequence of yet another order—a consequence by no means simple; since the various parts of the mass, being variously condensed, must be variously heated. Acting throughout a gaseous spheroid, of which the parts are unlike in their temperatures, the forces of aggregation and rotation must work a further series of changes: they must set up circulating currents, both general and local. At a later stage light as well as heat will be generated. Thus without dwelling on the likelihood of chemical combinations and electric disturbances, it is manifest that, supposing matter to have originally existed in a diffused state, the once uniform force which caused its aggregation must have become gradually divided into different forces; and that each further stage of complication in the resulting aggregate must have initiated further subdivisions of this force—a further multiplication of effects, increasing the previous heterogeneity.

This section of the argument may however be adequately sustained without having recourse to any such hypothetical illustra-

tions as the foregoing. The astronomical attributes of the Earth will, even by themselves, suffice for our purpose. Consider first the effects of its rotation. There is the oblateness of its form; there is the alternation of day and night; there are certain constant marine currents; and there are certain constant aërial currents. Consider next the secondary series of consequences due to the divergence of the Earth's plane of rotation from the plane of its orbit. The many variations of the seasons, both simultaneous and successive, which pervade its surface, are thus caused. External attraction of the Moon and Sun acting on the equatorial protuberance of this rotating spheroid with inclined axis, produces the motion called nutation, and that slower and larger one from which follows the precession of the equinoxes, with its several sequences. And then, by this same force, are generated the tides, aqueous and atmospheric.

Perhaps, however, the simplest way of showing the multiplication of effects among phenomena of this order, will be to set down the influences of any member of the Solar System on the rest. A planet directly produces in neighbouring planets certain appreciable perturbations, complicating those otherwise produced in them; and in the remoter planets it directly produces certain less visible perturbations. Here is a first series of effects. But each of the perturbed planets is itself a source of perturbations—each directly affects all the others. Hence, planet A having drawn planet B out of the position it would have occupied in A's absence, the perturbations which B causes are different from what they would else have been; and similarly with C, D, E, &c. Here then is a secondary series of effects; far more numerous though far smaller in their amounts. As these indirect perturbations must to some extent modify the movements of each planet, there results from them a tertiary series; and so on in ever multiplying and diminishing waves throughout the entire system.

§ 158. If the Earth was formed by the concentration of diffused matter, it must at first have been incandescent; and whether the nebular hypothesis be accepted or not, this original incandescence of the Earth may now be regarded as inductively established—or, if not established, at least rendered so probable that it is a

generally admitted geological doctrine. Several results of the gradual cooling of the Earth—as the formation of a crust, the solidification of sublimed elements, the precipitation of water, &c. —have been already noticed, and I again refer to them merely to point out that they are simultaneous effects of the one cause, diminishing heat. Let us now, however, observe the multiplied changes afterwards arising from the continuance of this one cause. The Earth, falling in temperature, must contract. Hence the solid crust at any time existing, is presently too large for the shrinking nucleus, and, being unable to support itself, inevitably follows the nucleus. But a spheroidal envelope cannot sink down into contact with a smaller internal spheroid, without disruption: it will run into wrinkles as the rind of an apple does when the bulk of its interior decreases from evaporation. As the cooling progresses and the envelope thickens, the ridges consequent on these contractions must become greater, rising ultimately into hills and mountains; and the later systems of mountains thus produced must not only be higher, as we find them to be, but must be longer, as we also find them to be. Thus, leaving out of view other modifying forces, we see what immense heterogeneity of surface arises from the one cause, loss of heat—a heterogeneity which the telescope shows us to be paralleled on the Moon, where aqueous and atmospheric agencies have been absent. But we have yet to notice another kind of heterogeneity of surface, simultaneously caused. While the Earth's crust was thin, the ridges produced by its contractions must not only have been small in height and length, but the tracts between them must have rested with comparative smoothness on the subjacent liquid spheroid; and the water in those arctic and antarctic regions where it first condensed, must have been evenly distributed. But as fast as the crust grew thicker and gained corresponding strength, the lines of fracture from time to time caused in it occurred at greater distances apart; the intermediate surfaces followed the contracting nucleus with less uniformity; and there consequently resulted larger areas of land and water. If any one, after wrapping an orange in tissue paper, and observing both how small are the wrinkles and how evenly the intervening spaces lie on the surface of the orange, will then wrap it in thick

cartridge-paper, and note both the greater height of the ridges and the larger spaces throughout which the paper does not touch the orange, he will see that as the Earth's solid envelope thickened, the areas of elevation and depression became greater. In place of islands more or less homogeneously scattered throughout an all-embracing sea, there must have gradually arisen heterogeneous arrangements of continent and ocean, such as we now know. These simultaneous changes in the extent and in the elevation of the lands, involved yet another species of heterogeneity—that of coast line. A tolerably even surface raised out of the ocean will have a simple, regular sea margin; but a surface varied by table lands and intersected by mountain chains will, when raised out of the ocean, have an outline extremely irregular, alike in its leading features and in its details. Thus endless is the accumulation of geological and geographical results brought about by this one cause—escape of the Earth's primitive heat.

When we pass from the agency which geologists term igneous, to aqueous and atmospheric agencies, we see a like ever-growing complication of effects. The denuding actions of air and water have, from the beginning, been modifying every exposed surface: everywhere working many different changes. As already said (§ 69), the original source of those gaseous and fluid motions which effect denudation is the solar heat. The transformation of this into various modes of energy, according to the nature and condition of the matter on which it falls, is the first stage of complication. The Sun's rays, striking at all angles a sphere that from moment to moment presented and withdrew different parts of its surface, and each of them for a different time daily throughout the year, would produce a considerable variety of changes even were the sphere uniform. But falling as they do on a sphere surrounded by an atmosphere containing wide areas of cloud, but which here unveils vast tracts of sea, there of level land, there of mountains, there of snow and ice, they cause in it countless different movements. Currents of air of all sizes, directions, velocities, and temperatures, are set up; as are also marine currents similarly contrasted in their characters. In this region the surface is giving off vapour; in that, dew is being precipitated; and in another rain

is descending—unlikenesses which arise from the changing ratio between the absorption and radiation of heat in each place. At one hour a rapid fall in temperature leads to the formation of ice, with an accompanying expansion throughout the moist bodies frozen; while at another a thaw unlocks the dislocated fragments of these bodies. And then, passing to a second stage of complication, we see that the many kinds of motion directly or indirectly caused by the Sun's rays, severally produce results which vary with the conditions. Oxidation, drought, wind, frost, rain, glaciers, rivers, waves, and other denuding agents effect disintegrations that are determined in their amounts and qualities by local circumstances. Acting on a tract of granite, such agents here work scarcely an appreciable effect; there cause exfoliations of the surface and a resulting heap of *débris* and boulders; and elsewhere, after decomposing the feldspar into a white clay, carry away this with the accompanying quartz and mica, and deposit them in separate beds, fluviatile or marine. When the exposed land consists of several unlike formations, sedimentary and igneous, changes proportionately more heterogeneous are wrought. The formations being disintegrable in different degrees, there follows an increased irregularity of surface. The areas drained by adjacent rivers being differently constituted, these rivers carry down to the sea unlike combinations of ingredients; and so sundry new strata of distinct compositions arise. And here, indeed, we may see very clearly how the heterogeneity of the effects increases in a geometrical progression with the heterogeneity of the object acted upon. Let us, for the fuller elucidation of this truth in relation to the inorganic world, consider what would follow from an extensive cosmical castastrophe—say a great subsidence throughout Central America. The immediate results would themselves be sufficiently complex. Besides the numberless dislocations of strata, the ejections of igneous matter, the propagation of earthquake vibrations many thousands of miles around, the loud explosions, and the escape of gases, there would be an inrush of the Atlantic and Pacific Oceans, a subsequent recoil of enormous waves, which would traverse both these oceans and produce myriads of changes along their shores, and corresponding atmospheric waves complicated by the currents surrounding each volcanic vent, as well as

electrical discharges with which eruptions are accompanied. But these temporary effects would be insignificant compared with the permanent ones. The complex currents of the Atlantic and Pacific would be altered in their directions and amounts. The distribution of heat achieved by these currents would be different from what it is. The arrangement of the isothermal lines, not only on the neighbouring continents but even throughout Europe, would be changed. The tides would flow differently from what they do now. There would be more or less modification of the winds in their periods, strengths, directions, qualities; and rain would fall scarcely anywhere at the same times and in the same quantities as at present. In these many changes, each including countless minor ones, may be seen the immense heterogeneity of the results wrought out by one force, when that force expends itself on a previously complicated area: the implication being that from the beginning the complication has advanced at an increasing rate.

§ 159. We have next to trace throughout organic evolution, this same all-pervading principle. And here, where the transformation of the homogeneous into the heterogeneous was first observed, the production of many changes by one cause is least easy to demonstrate in a direct way. Heredity complicates everything. Nevertheless, by indirect evidence we may establish our proposition.

By way of preparation observe how numerous are the changes which any marked stimulus works on an adult organism—a human being for instance. An alarming sound or sight, besides impressions on the organs of sense and the nerves, may produce a start, a scream, a distortion of the face, a trembling consequent on general muscular relaxation, a burst of perspiration, and perhaps an arrest of the heart followed by syncope; and if the system be feeble, an illness with its long train of complicated symptoms may set in. Similarly in cases of disease. A minute portion of the small-pox virus taken into the system will, in a severe case, cause, during the first stage, rigors, heat of skin, accelerated pulse, furred tongue, loss of appetite, thirst, epigastric uneasiness, vomiting, headache, pains in the back and limbs, muscular weakness, convulsions, delirium, &c.; in the second stage, cutaneous eruption,

itching, tingling, sore throat, swelled fauces, salivation, cough, hoarseness, dyspnœa, &c.; and in the third stage, œdematous inflammations, pneumonia, pleurisy, diarrhœa, inflammation of the brain, ophthalmia, erysipelas, &c.: each of which enumerated symptoms is itself more or less complex. Now it needs only to consider that this working of many changes by one force on an adult organism, must be partially paralleled in an embryo organism, to understand that in it too there must be a multiplication of effects, ever tending to produce increasing heterogeneity. Each organ as it is developed, serves, by its actions and reactions on the rest, to initiate new complexities. The first pulsations of the fœtal heart must simultaneously aid the unfolding of every part. The growth of each tissue, by taking from the blood special proportions of elements, must modify the constitution of the blood; and so must modify the nutrition of all the other tissues. The distributive actions, implying as they do a certain waste, necessitate an addition to the blood of effete matters, which must influence the rest of the system, and perhaps, as some think, initiate the formation of excretory organs. The nervous connexions established among the viscera must further multiply their mutual influences. And so is it with every modification of structure—every additional part and every alteration in the ratios of parts. Proof of a more direct kind is furnished by the fact, that the same germ may be evolved into different forms according to circumstances. Thus, during its earliest stages, every germ is sexless—originates either male or female as the balance of forces acting on it determines. Again, there is the familiar truth that the larva of a working-bee will develop into a queen-bee if, before a certain period, it is fed after a manner like that in which the larvæ of queen-bees are fed. Then there is the still more striking evidence furnished by ants and termites. Riley, Grassi, Haviland and Hart, have shown that differences of nutrition not only originate the differences between males and females but also the different traits of soldiers, workers, and nurses.* Varying degree of nutrition, after initiating the unlikeness of sex, then determines the unlikenesses of external organs possessed by the various classes of sexless individuals. Next comes

* See *Principles of Biology*, vol. 1, pp. 680–8.

the evidence, still more directly relevant, supplied by the effects of castration. If the removal of certain organs prevents the development of certain other organs in remote parts of the system—in man the vocal structures, the beard, some traits of general form, some instincts and other mental characters—then it is clear that where these organs have not been removed, the presence of them determines the occurrence of these various changes of development, and doubtless many minor ones which are unobtrusive. Here the fact that one cause produces many effects in the course of organic evolution is indisputable. Doubtless we are, and must ever continue, unable to conceive those mysterious properties which make the germ when subject to fit influences undergo the special changes initiating, and mainly constituting, the transformations of an unfolding organism; though we may consistently suppose that they represent an infinite series of inherited modifications consequent on the instability of the homogeneous, the multiplication of effects, and one further factor still to be set forth. All here contended is that, given a germ possessing these mysterious properties, the evolution of an organism from it depends, in part, on that multiplication of effects which we have seen to be one cause of evolution in general, so far as we have yet traced it.

When, leaving the development of single plants and animals, we pass to that of the Earth's Flora and Fauna, the course of the argument again becomes clear and simple. Though, as before admitted, the fragmentary facts Palæontology has accumulated, do not clearly warrant us in saying that, in the lapse of geologic time, there have been evolved more heterogeneous organisms, and more heterogeneous assemblages of organisms; yet we shall now see that there must ever have been a tendency towards these results. We shall find that the production of many effects by one cause, which, as already shown, has been all along increasing the physical heterogeneity of the Earth, has further necessitated an increasing heterogeneity of its inhabiting organisms, individually and collectively. An illustration will make this clear. Suppose that by upheavals, occurring, as they are known to do, at long intervals, the East Indian Archipelago were raised into a continent, and a chain of mountains formed along the axis of elevation. By

the first of these upheavals, the plants and animals of Borneo, Sumatra, New Guinea, and the rest, would be subjected to slightly-modified sets of conditions. The climate of each would be altered in temperature, in humidity, and in its periodical variations, while the local differences would be multiplied. The modifications would affect, perhaps inappreciably, the entire Flora and Fauna of the region. The change of level would entail additional modifications, varying in different species, and also in different members of the same species, according to their distance from the axis of elevation. Plants growing only on the sea-shore in special localities might become extinct. Others, living only in swamps of a certain humidity, would, if they survived at all, probably undergo visible changes of appearance. While more marked alterations would occur in some of the plants that spread over the lands newly raised out of the water. The animals and insects living on these modified plants, would themselves be in some degree modified by changes of food, as well as by changes of climate; and the modifications would be more marked where, from the dwindling or disappearance of one kind of plant, an allied kind was eaten. In the lapse of the many generations arising before the next upheaval, the sensible or insensible alterations thus produced in each species, would become organized—in all the races which survived there would be more or less adaptation to the new conditions. The next upheaval would superinduce further organic changes, implying wider divergences from the primary forms; and so repeatedly. Now, however, observe that this revolution would not be a substitution of a thousand modified species for the thousand original species; but in place of the thousand original species there would arise several thousand species, or varieties, or changed forms. Each species being distributed over an area of some extent, and tending continually to colonize the new area exposed, its different members would be subject to different sets of changes. Plants and animals migrating towards the equator would not be affected in the same way with others migrating from it. Those which spread towards the new shores, would undergo changes unlike the changes undergone by those which spread into the mountains. Thus, each original race of organisms would become the root from which diverged several

races, differing more or less from it and from one another; and while some of these might subsequently disappear, probably more than one would survive into the next geologic period. Not only would certain modifications be thus caused by changes of physical conditions and food, but also, in some cases, other modifications caused by changes of habit. The fauna of each island, peopling, step by step, the newly-raised tracts, would eventually come in contact with the faunas of other islands; and some members of these other faunas would be unlike any creatures before seen. Herbivores meeting with new beasts of prey would, in some cases, be led into modes of defence or escape differing from those previously used; and simultaneously the beasts of prey would modify their modes of pursuit and attack. We know that when circumstances demand it, such changes of habit *do* take place in animals; and we know that if the new habits become the dominant ones, they must eventually in some degree alter the organization. Note, now, a further consequence. There must arise not simply a tendency towards the differentiation of each race of organisms into several races; but also a tendency to the occasional production of a somewhat higher organism. Taken in the mass, these divergent varieties, which have been caused by fresh physical conditions and habits of life, will exhibit alterations quite indefinite in kind and degree, and alterations that do not necessarily constitute an advance. Probably in most cases the modified type will be not appreciably more heterogeneous than the original one. But it *must* now and then occur that some division of a species, falling into circumstances which give it rather more complex experiences, and demand actions somewhat more involved, will have certain of its organs further differentiated in proportionately small degrees—will become slightly more heterogeneous. Hence, there will from time to time arise an increased heterogeneity both of the Earth's flora and fauna, and of individual races included in them. Omitting detailed explanations, and allowing for qualifications which cannot here be specified, it is sufficiently clear that geological mutations have all along tended to complicate the forms of life, whether regarded separately or collectively. That multiplication of effects which has been a part cause of the transformation of the Earth's crust from the

simple into the complex, has simultaneously led to a parallel transformation of the Life upon its surface.*

The deduction here drawn from the established truths of geology and the general laws of life, gains immensely in weight on finding it to be in harmony with an induction drawn from direct experience. Just that divergence of many races from one race, above described as continually occurring during geologic time, we know to have occurred during the pre-historic and historic periods, in man and domestic animals. And just that multiplication of effects which we concluded must have been instrumental to the first, we see has in great measure wrought the last. Single causes, as famine, pressure of population, war, have periodically led to further dispersions of men and of dependent creatures: each such dispersion initiating new modifications, new varieties. Whether all the human races be or be not derived from one stock, philology shows that in many cases a group of races, now easily distinguishable from one another, was originally one race—that the diffusion of one race into different regions and conditions of existence has produced many altered forms of it. Similarly with domestic animals. Though in some cases, as that of dogs, community of origin will perhaps be disputed, yet in other cases, as that of the sheep or the cattle of our own country, it will not be questioned that local differences of climate, food, and treatment, have transformed one original breed into many breeds, now become so far distinct as to produce unstable hybrids. Moreover, through the complication of effects flowing from single causes, we here find,

* Had this paragraph, first published in the *Westminster Review* in April, 1857, been written after the appearance of Mr. Darwin's work on *The Origin of Species*, instead of before, it would doubtless have been otherwise expressed. Reference would have been made to the process of "natural selection," as greatly facilitating the differentiations described. As it is, however, I prefer to let the passage stand in its original shape; partly because it seems to me that these successive changes of conditions would produce divergent varieties or species, apart from the influence of "natural selection" (though in less numerous ways as well as less rapidly); and partly because I conceive that in the absence of these successive changes of conditions, "natural selection" would effect comparatively little. Let me add that though these positions are not enunciated in *The Origin of Species*, yet a common friend gives me reason to think that Mr. Darwin would coincide in them.

what we before inferred, not only an increase of general heterogeneity, but also of special heterogeneity. While of the divergent divisions and subdivisions of the human race, many have undergone changes not constituting an advance; others have become more heterogeneous. The civilized European departs more widely from the mammalian archetype than does the Australian.

§ 160. A sense-impression does not expend itself in arousing some single state of consciousness; but the state of consciousness aroused is made up of various represented sensations connected by co-existence or sequence with the presented sensation. And that, in proportion as the grade of intelligence is high, the number of ideas suggested is great, may be readily inferred. Let us, however, look at the proof that here, too, each change is the parent of many changes and that the multiplication increases in proportion as the area affected is complex.

Were some hitherto unknown bird, driven by stress of weather from the remote north, to make its appearance on our shores, it would excite no speculation in the sheep or cattle amid which it alighted: a perception of it as a creature like those constantly flying about, would be the sole interruption of that dull current of consciousness which accompanies grazing and rumination. The cow-herd, by whom we may suppose the exhausted bird to be presently caught, would probably gaze at it with some slight curiosity, as being unlike any he had before seen—would note its most conspicuous markings, and vaguely ponder on the questions, where it came from, and how it came. By the sight of it, the village bird-stuffer would have suggested to him sundry forms to which it bore a little resemblance; would receive from it more numerous and more specific impressions respecting structure and plumage; would be reminded of other birds brought by storms from foreign parts; would tell who found them, who stuffed them, who bought them. Supposing the unknown bird taken to a naturalist of the old school, interested only in externals, (one of those described by Edward Forbes, as examining animals as though they were skins filled with straw,) it would excite in him a more involved series of mental changes. There would be an elaborate examination of the feathers, a noting of all their technical distinc-

tions, with a reduction of these perceptions to certain equivalent written symbols; reasons for referring the new form to a particular family, order, and genus would be sought out and written down; communications with the secretary of some society, or editor of some journal, would follow; and probably there would be not a few thoughts about the addition of the *ii* to the describer's name, to form the name of the species.

Lastly, in the comparative anatomist such a new species, should it have any marked internal peculiarity, might produce additional sets of changes—might suggest modified views respecting the relationships of the division to which it belonged; or, perhaps, alter his conceptions of the homologies and developments of certain organs; and the conclusions drawn might possibly enter as elements into still wider inquiries concerning the origin of organic forms.

From ideas let us turn to emotions. In a young child, a father's anger produces little else than vague fear—a sense of impending evil, taking various shapes of physical suffering or deprivation of pleasures. In elder children the same harsh words will arouse additional feelings: sometimes a sense of shame, of penitence, or of sorrow for having offended; at other times, a sense of injustice and a consequent anger. In the wife, yet a further range of feelings may come into existence—perhaps wounded affection, perhaps self-pity for ill-usage, perhaps contempt for groundless irritability, perhaps sympathy for some suffering which the irritability indicates, perhaps anxiety about an unknown misfortune which she thinks has produced it. Nor are we without evidence that among adults, the like differences of development are accompanied by like differences in the number of emotions aroused, in combination or rapid succession: the lower natures being characterized by that impulsiveness which results from the uncontrolled action of a few feelings; and the higher natures being characterized by the simultaneous action of many secondary feelings, modifying those first awakened.

Perhaps it will be objected that the illustrations here given, are drawn from the functional changes of the nervous system, not from its structural changes; and that what is proved among the first does not necessarily hold among the last. This must be admitted. Those, however, who recognize the truth that the structural

changes are the slowly accumulated results of the functional changes, will readily draw the corollary that a part cause of the evolution of the nervous system, as of other evolution, is this multiplication of effects which becomes ever greater as the development becomes higher.

§ 161. If the advance of Man towards greater heterogeneity, in both body and mind, is in part traceable to the production of many effects by one cause, still more clearly may the advance of Society towards greater heterogeneity be so explained.

Consider the growth of industrial organization. When some individual of a tribe displays unusual aptitude for making weapons, which were before made by each man for himself, there arises a tendency towards the differentiation of that individual into a maker of weapons. His companions, warriors and hunters all of them, severally wishing to have the best weapons that can be made, are certain to offer strong inducements to this skilled individual to make weapons for them. He, on the other hand, having both an unusual faculty, and an unusual liking, for making weapons (capacity and desire being commonly associated), is predisposed to fulfil these commissions on the offer of adequate rewards: especially as his love of distinction is also gratified. This first specialization of function, once commenced, tends ever to become more decided. On the side of the weapon-maker, continued practice gives increased skill. On the side of his clients, cessation of practice entails decreased skill. Thus this social movement tends to become more decided in the direction in which it was first set up; and the incipient heterogeneity is, on the average of cases, likely to become permanent for that generation, if no longer. Such a differentiation has a tendency to initiate other differentiations. The advance described implies the introduction of barter. The maker of weapons has to be paid in such other articles as he agrees to take. Now he will not habitually exchange for one kind of article. He does not want mats only, or skins, or fishing-gear. He wants all these, and on each occasion will bargain for the particular things he then most needs. What follows? If among the members of the tribe there exist any slight differences of skill in the manufacture of these various things the weapon-maker will take from each one the thing which that one excels in making.

But he who has bartered away his mats or his fishing-gear, must make other mats or fishing-gear for himself; and in so doing must, in some degree, further develop his aptitude. If such transactions are repeated, these specializations may become appreciable. And whether or not there ensue distinct differentiations of other individuals into makers of particular articles, it is clear that the one original cause produces not only the first dual effect, but a number of secondary dual effects, like in kind but minor in degree. This process, of which traces may be seen among groups of school-boys, cannot well produce a lasting distribution of functions in an unsettled tribe; but where there grows up a fixed and multiplying community, it will become permanent, and increase with each generation. An addition to the number of citizens, involving a greater demand for every commodity, intensifies the functional activity of each specialized person or class; and this renders the specialization more definite where it exists, and establishes it where it is nascent. By increasing the pressure on the means of subsistence, a larger population again augments these results; since every individual is forced more and more to confine himself to that which he can do best, and by which he can gain most. And this industrial progress opens the way for further growth of population, which reacts as before. Under the same stimuli new occupations arise. Among competing workers, some discover better processes or better materials. The substitution of bronze for stone entails on him who first makes it a great increase of demand—so great an increase that presently all his time is occupied in making the bronze for the articles he sells, and he is obliged to depute the fashioning of these articles to others; so that eventually the making of bronze, thus differentiated from a pre-existing occupation, becomes an occupation by itself. But now mark the ramified changes which follow this change. Bronze soon replaces stone not only in the articles it was first used for, but in many others; and so affects the manufacture of them. Further, it affects the processes which such improved utensils subserve, and the resulting products—modifies buildings, carvings, dress, personal decorations. And all these changes react on the people—increase their manipulative skill, their intelligence, their comfort—refine their habits and tastes.

This increasing social heterogeneity, that results from the production of many effects by one cause, cannot of course be followed out. But leaving the intermediate phases of social development, let us take an illustration from its passing phase. To trace the effects of steam-power, in its manifold applications to mining, navigation, and manufactures, would carry us into unmanageable detail. Let us confine ourselves to the latest embodiment of steam power—the locomotive engine. This, as the proximate cause of our railway system, has changed the face of the country, the course of trade, and the habits of the people. Consider, first, the complicated sets of changes that precede the making of every railway—the provisional arrangements, the meetings, the registration, the trial section, the parliamentary survey, the lithographed plans, the books of reference, the local deposits and notices, the application to Parliament, the passing Standing Orders Committee, the first, second, and third readings: each of which brief heads indicates a multiplicity of transactions, and a further development of sundry occupations, (as those of engineers, surveyors, lithographers, parliamentary agents, share-brokers,) and the creation of sundry others (as those of traffic takers, reference makers). Consider, next, the yet more marked changes implied in railway construction—the cuttings, embankings, tunnellings, diversions of roads; the building of bridges, viaducts, and stations; the laying down of ballast, sleepers, and rails; the making of engines, tenders, carriages, and wagons: which processes, acting upon numerous trades, increase the importation of timber, the quarrying of stone, the manufacture of iron, the mining of coal, the burning of bricks; institute a variety of special manufactures weekly advertised in the *Railway Times;* and call into being some new classes of workers—drivers, stokers, cleaners, plate-layers, signal-men. Then come the changes, more numerous and involved still, which railways in action produce on the community at large. The organization of every business is modified. Ease of communication makes it better to do directly what was before done by proxy; agencies are established where previously they would not have paid; goods are obtained from remote wholesale houses instead of near retail ones; and commodities are used which distance once rendered inaccessible. Rapidity and economy of

carriage tend to specialize more than ever the industries of different districts—to confine each manufacture to the parts in which, from local advantages, it can be best carried on. Cheap distribution equalizes prices, and also, on the average, lowers prices: thus bringing divers articles within the reach of those before unable to buy them. At the same time the practice of travelling is immensely extended. People who before could not afford it, take annual trips to the sea, visit their distant relations, make tours, and so are benefited in body, feelings, and intellect. The prompter transmission of letters and of news produces further changes—makes the pulse of the nation faster. Yet more, there arises a wide dissemination of cheap literature through railway book-stalls, and of advertisements in railway carriages: both of them aiding ulterior progress. So that beyond imagination are the changes, thus briefly indicated, consequent on the invention of the locomotive engine.

It should be added that we here see, more clearly than ever, how in proportion as the area over which any influence extends becomes heterogeneous, the results are in a yet higher degree multiplied in number and kind. While among the uncivilized men to whom it was first known, caoutchouc caused but few changes, among ourselves the changes have been so many and varied that the history of them occupies a volume. Upon the small, homogeneous community inhabiting one of the Hebrides, the electric telegraph would produce, were it used, scarcely any results; but in England the results it produces are multitudinous.

Space permitting, the synthesis might here be pursued in relation to all the subtler products of social life. It might be shown how, in Science, an advance of one division presently advances other divisions—how Astronomy has been immensely forwarded by discoveries in Optics, while other optical discoveries have initiated Microscopic Anatomy, and greatly aided the growth of Physiology—how Chemistry has indirectly increased our knowledge of Electricity, Magnetism, Biology, Geology—how Electricity has reacted on Chemistry and Magnetism, developed our views of Light and Heat, and disclosed sundry laws of nervous action. But it would needlessly tax the reader's patience to detail, in their many ramifications, these various changes; so involved and subtle as to be followed with difficulty.

§ 162. After the argument which closed the last chapter, a parallel one here seems scarcely required. For symmetry's sake, however, it will be proper briefly to point out how the multiplication of effects, like the instability of the homogeneous, is a corollary from the persistence of force.

Things which we call different are things which react in different ways; and we can know them as different only by the differences in their reactions. When we distinguish bodies as hard or soft, rough or smooth, we mean that certain like muscular forces expended on them are followed by unlike reactive forces, causing unlike sets of sensations. Objects classed as red, blue, yellow, &c., are objects which decompose light in contrasted ways; that is, we know contrasts of colour as contrasts in the changes produced in a uniform incident force. The proposition that the different parts of any whole must react differently on a uniform incident force, and must thus reduce it to a gronp of multiform forces, is in essence a truism. Suppose we reduce this truism to its lowest terms.

When, from unlikeness between the effects they produce on consciousness, we predicate unlikeness between two objects, what is our warrant? and what do we mean by the unlikeness, objectively considered? Our warrant is the persistence of force. Some kind or amount of change has been wrought in us by the one which has not been wrought by the other. This change we ascribe to some force exercised by the one which the other has not exercised. And we have no alternative but to do this, or to assert that the change had no antecedent, which is to deny the persistence of force. Whence it is further manifest that what we regard as the objective unlikeness is the presence in the one of some force, or set of forces, not present in the other—something in the kinds or amounts or directions of the constituent forces of the one, which those of the other do not parallel. But now if things or parts of things which we call different, are those of which the constituent forces differ in one or more respects, what must happen to any like forces, or any uniform force, falling on them? Such like forces, or parts of a uniform force, must be differently modified. The force which is present in the one and not in the other, must be an element in the conflict—must produce its equivalent reaction; and must so affect the total reaction. To say otherwise is to say that this differential

force will produce no effect, which is to say that force is not persistent.

I need not develop this corollary further. It manifestly follows that a uniform force falling on a uniform aggregate, must undergo dispersion; that falling on an aggregate made up of unlike parts, it must undergo dispersion from each part, as well as qualitative differentiations; that in proportion as the parts are unlike, these qualitative differentiations must be marked; that in proportion to the number of the parts, they must be numerous; that the secondary forces so produced must undergo further transformations while working equivalent transformations in the parts that change them; and similarly with the forces they generate. Thus the conclusions that a part cause of Evolution is the multiplication of effects, and that this increases in geometrical progression as the heterogeneity becomes greater, are not only to be established inductively, but are deducible from the deepest of all truths.

## CHAPTER XXI

### SEGREGATION

§ 163. The general interpretation of Evolution is far from being completed in the preceding chapters. We must contemplate its changes under yet another aspect, before we can form a definite conception of the process constituted by them. Though the laws already set forth furnish a key to the re-arrangement of parts which Evolution exhibits, in so far as it is an advance from the uniform to the multiform, they furnish no key to this re-arrangement in so far as it is an advance from the indefinite to the definite. On studying the actions and reactions everywhere going on, we have found it to follow from a certain primordial truth, that the homogeneous must lapse into the heterogeneous, and that the heterogeneous must become more heterogeneous; but we have not discovered why the differently-affected parts of any simple whole, become clearly marked off from one another, at the same time that they become unlike. Thus far no reason has been given why there should not ordinarily arise a vague chaotic heterogeneity, in place of that orderly heterogeneity displayed in Evolution. It still remains to find out the cause of that local integration which accompanies local differentiation—that gradually-completed segregation of like units into a group, distinctly separated from neighbouring groups which are severally made up of other kinds of units. The rationale will be conveniently introduced by a few instances in which we may watch this segregative process taking place.

When, late in September, the trees are gaining their autumn colours, and we are hoping soon to see a further change increasing the beauty of the landscape, we are sometimes disappointed by the

occurrence of an equinoctial gale. Out of the mixed mass of foliage on each branch, the strong current of air carries away the decaying and brightly-tinted leaves, but fails to detach those which are still green. And while these last, frayed and seared by long-continued beatings against one another, give a sombre colour to the woods, the red and yellow and orange leaves are collected together in ditches and behind walls and in corners where eddies allow them to settle. That is to say, by that uniform force which the wind exerts on both kinds, the dying leaves are picked out from among their still-living companions and gathered in places by themselves. Again, the separation of particles of different sizes, as dust and sand from pebbles, may be similarly effected, as we see on every road in March. And from the days of Homer downwards, the power of currents of air, natural and artificial, to part from one another units of unlike characters, has been habitually utilized in the winnowing of chaff from wheat. In every brook we see how the mixed materials carried down are separately deposited—how in rapids the bottom gives rest to nothing but boulders and pebbles; how where the current is not so strong, sand is let fall; and how, in still places, there is a sediment of mud. This selective action of moving water is commonly applied in the arts to obtain masses of particles of different degrees of fineness. Emery, for example, after being ground, is carried by a slow current through successive compartments; in the first of which the largest grains subside; in the second of which the grains that settle before the water has escaped, are somewhat smaller; in the third smaller still; until in the last there are deposited those finest particles which have not previously been able to reach the bottom. And in a way that is different though equally significant, this segregative effect of water in motion, is exemplified in the carrying away of soluble from insoluble matters—an application of it hourly made in every laboratory. The effects of the uniform forces which aërial and aqueous currents exercise, are paralleled by those of uniform forces of other orders. Electric attraction will separate small bodies from large, or light bodies from heavy. By magnetism, grains of iron may by selected from other grains; as by the Sheffield grinder, whose magnetized gauze mask filters out the steel dust his wheel gives off from the stone dust which accompanies it.

And how the affinity of any agent acting differently on the mixed components of a body, enables us to take away some component and leave the rest behind, is perpetually shown in chemical experiments.

What, now, is the general truth here variously presented? How are these facts, and countless similar ones, to be expressed in terms that embrace them all? In each case we see in action a force which may be regarded as simple or uniform—fluid motion in a certain direction at a certain velocity; electric or magnetic attraction of a given amount; chemical affinity of a particular kind; or rather, in strictness, the acting force is compounded of one of these with some other uniform force, as gravitation, &c. In each case we have an aggregate made up of unlike units—either atoms of different substances combined or intimately mingled, or fragments of the same substance of different sizes, or other constituent parts that are unlike in their specific gravities, shapes, or other attributes. And in each case these unlike units, or groups of units, of which the aggregate consists, are, under the influence of some resultant force acting indiscriminately on them all, separated from one another—segregated into minor aggregates, each consisting of units that are severally like one another and unlike those of the other minor aggregates. Such being the common aspect of these changes, let us look for the common interpretation of them.

In the chapter on "The Instability of the Homogeneous," it was shown that a uniform force falling on any aggregate, produces unlike modifications in its different parts—turns the uniform into the multiform and the multiform into the more multiform. The transformation thus wrought, consists of either insensible or sensible changes of relative position among the units, or of both. Such portion of the permanently effective force as reaches each different part, or differently-conditioned part, may be expended in modifying the mutual relations of its constituents; or it may be expended in moving the part to another place; or it may be expended partially in the first and partially in the second. And if little or none is absorbed in re-arranging the components of a compound unit, much or the whole must show itself in motion of such compound unit to some other place in the aggregate; and

conversely. What must follow from this? In cases where none or only part of the force generates chemical re-distributions, what physical re-distributions must be generated? Parts that are similar to each other will be similarly acted on by the force, while parts that are dissimilar will be dissimilarly acted on. Hence the permanently effective incident force, when wholly or partially transformed into mechanical motion of the units, will produce like motions in units that are alike, and unlike motions in units that are unlike. If then, in an aggregate containing two or more orders of mixed units, those of the same order will be moved in the same way, and in a way that differs from that in which units of other orders are moved, the respective orders must segregate. A group of like things on which are impressed motions that are alike in amount and direction, must be transferred as a group to another place, and if they are mingled with some group of other things, on which the motions impressed are like one another, but unlike those of the first group in amount or direction or both, these other things must be transferred as a group to some other place—the mixed units must undergo a simultaneous selection and separation.

Further to elucidate this process, let me set down a few instances in which we may see that the definiteness of the separation is in proportion to the definiteness of the differences among the units. Take a handful of pounded substance, containing fragments of all sizes, and let it fall gradually while a gentle breeze is blowing. The large fragments will be collected on the ground almost immediately under the hand; somewhat smaller fragments will be carried a little to the leeward; still smaller ones further away; and those minute particles we call dust, will be drifted far before they reach the earth: that is, the segregation is indefinite where the differences among the fragments are indefinite, though the divergences are greatest where the differences are greatest. If, again, the handful be made up of distinct orders of units—as pebbles, coarse sand, and dust—these will, under like conditions, be segregated with greater definiteness. The pebbles will drop almost vertically; the sand, falling obliquely, will deposit itself within a tolerably circumscribed space beyond the pebbles; while the dust will be blown almost horizontally to a great distance.

A case in which another kind of force comes into play, will still better illustrate this truth. Through a mixed aggregate of soluble and insoluble substances, let water slowly percolate. There will in the first place be a distinct parting of the substances that are the most widely unlike: the soluble will be carried away; the insoluble will remain behind. Further, some separation, though a less definite one, will be effected among the soluble substances; since the first part of the current will remove the most soluble in the largest amounts, and after these have been dissolved, it will continue to bring out the remaining less soluble. Even the undissolved matters will have simultaneously undergone some segregation; for the percolating fluid will carry down the minute fragments from among the large ones, and will often deposit those of small specific gravity in one place, and those of great specific gravity in another. To complete the elucidation we must glance at the obverse fact; namely, that mixed units which differ but slightly, are moved in but slightly-different ways by incident forces, and can therefore be separated only by such adjustments of the incident forces as allow slight differences to become appreciable factors in the result. The parting of alcohol from water by distillation is a good example. Here we have molecules consisting of oxygen and hydrogen, mingled with molecules consisting of oxygen, hydrogen, and carbon. The two orders of molecules have a considerable likeness of nature: they similarly maintain a fluid form at ordinary temperatures; they similarly become gaseous more and more rapidly as the temperature is raised; and they boil at points not very far apart. Now this comparative likeness of the molecules is accompanied by difficulty in segregating them. If the mixed fluid is unduly heated, much water distils over with the alcohol: it is only within a narrow range of temperature that molecules of the one kind are driven off rather than the others; and even then not a few of the others accompany them. The most interesting and instructive example, however, is furnished by certain phenomena of crystallization. When several salts that have little analogy of constitution, are dissolved in the same body of water, they are separated without much trouble, by crystallization: subject as they are to uniform forces, they segregate. The crystals of each salt do, indeed, usually contain certain small

amounts of the other salts present in the solution; but from these they are severally freed by repeated re-solutions and crystallizations. Mark now, however, that the reverse is the case when the salts contained in the same body of water are chemically homologous. The nitrates of baryta and lead, or the sulphates of zinc, soda, and magnesia, unite in the same crystals; nor will they crystallize separately if these crystals be dissolved afresh, and afresh crystallized. On seeking the cause of this anomaly, chemists found that such salts were isomorphous—that their molecules, though not chemically identical, are identical in the proportions of acid, base, and water, composing them, and in the crystalline forms they assume when uniting. Here, then, we see clearly that units of unlike kinds are selected out and separated with a readiness proportionate to the degree of their unlikeness.

There is a converse cause of segregation which it is needless here to treat of with equal fulness. If different units, acted on by the same force, must be differently moved; so, conversely, units of the same kind must be differently moved by different forces. Supposing some group of units forming part of a homogeneous aggregate are unitedly exposed to a force which is unlike in amount or direction to the force acting on the rest of the aggregate, then this group of units will separate from the rest, provided that, of the force so acting on it, there remains any portion not dissipated in molecular vibrations or absorbed in producing molecular re-arrangements. After all that has been said above, this proposition needs no defence.

Before ending our preliminary exposition, a complementary truth must be specified; namely, that mixed forces are segregated by the reaction of uniform matters, just as mixed matters are segregated by the action of uniform forces. Of this truth a complete and sufficient illustration is furnished by the dispersion of refracted light. A beam of light, made up of ethereal undulations of different orders, is not uniformly deflected by a homogeneous refracting body; but the different orders of undulations it contains are deflected at different angles: the result being that these different orders of undulations are separated and integrated, and so produce the colours of the spectrum. A segregation of another kind occurs when rays of light traverse an obstructing medium.

Those which consist of comparatively short undulations are absorbed before those which consist of comparatively long ones; and the red rays, which consist of the longest undulations, alone penetrate when the obstruction is very great. How, conversely, there is produced a separation of like forces by the reaction of unlike matters, is also made manifest by the phenomena of refraction; since adjacent and parallel beams of light, falling on, and passing through, unlike substances, are made to diverge.

§ 164. In vague ways the heavenly bodies exemplify that cause of material segregation last assigned—the action of unlike forces on like units.

I say in vague ways because our Sidereal System displays more of aggregation than of segregation. That the irregular swarms of stars constituting the Milky Way, with its branches and gaps and denser regions, have been gathered together from a more widely diffused state, may be reasonably inferred; though as we know nothing of the preceding distribution such a change cannot be proved: still less can there be proved a segregative process.

It is true that in clusters of stars, beginning with those having members considerably dispersed and ending with those having members closely concentrated—globular clusters—we see strong evidence of aggregation; and it may be contended that since the mutual gravitations of the stars forming a cluster, differ in their degrees and directions from those of the stars from which they have separated, there is a kind of seregation. But it must be admitted that the conformity to the above-named principle is but an indefinite one.

There are, however, two classes of facts which exhibit segregation, though they leave us ignorant of its causes. The first is that star-clusters are abundant along the course of the Milky Way: by far the larger number of them lying in the neighbourhood of its plane and relatively few in regions on either side. The second is that, contrariwise, the nebulæ are sparsely scattered in and about the galactic circle and are relatively numerous in the spaces remote from it. Though there are thus presented two cases of segregation there is no evidence that these different classes of bodies have been separated from a mixed assemblage, nor is there any indication of

the forces by which this contrast in distribution has been produced. We can only say that the facts are congruous with the belief that segregation, probably indirect rather than direct in its cause, has been going on.

The formation and detachment of a nebulous ring illustrates the same general principle. To conclude, as Laplace did, that the equatorial portion of a rotating nebulous spheroid will, during concentration, acquire a centrifugal force sufficient to prevent it from following the rest of the contracting mass, is to conclude that such portions will remain behind as are in common subject to a certain differential force. The line of division between the ring and the spheroid, must be a line inside of which the aggregative force is greater than the force resisting aggregation; and outside of which the force resisting aggregation is greater than the aggregative force. Hence the alleged process conforms to the law that among like units, exposed to unlike forces, the similarly conditioned separate from the dissimilarly conditioned.

§ 165. Those geologic changes usually classed as aqueous, display under numerous forms the segregation of unlike units by a uniform incident force. On sea shores the waves are ever sorting out and separating the mixed materials against which they break. From each mass of fallen cliff, the tide carries away all those particles which are so small as to remain long suspended in the water; and, at some distance from shore, deposits them in the shape of fine sediment. Large particles, sinking with comparative rapidity, are accumulated into beds of sand near low water-mark. The small pebbles collect together at the bottom of the incline up which the breakers rush; and on the top lie the larger stones and boulders. Still more specific segregations may occasionally be observed. Flat pebbles, produced by the breaking down of laminated rock, are sometimes separately collected in one part of a shingle bank. On this shore the deposit is wholly of mud; on that it is wholly of sand. Here we find a sheltered cove filled with small pebbles almost of one size; and there, in a curved bay one end of which is more exposed than the other, we see a progressive increase in the massiveness of the stones as we walk from the less exposed to the more exposed end. Trace the history of each

geologic deposit, and we are quickly led down to the fact that mixed fragments of matter, differing in their sizes or weights, are, when exposed to the momentum and friction of water, joined with the attraction of the Earth, selected from one another, and united into groups of comparatively like fragments. And we see that, other things equal, the separation is definite in proportion as the differences of the units are marked. After they have been formed, sedimentary strata exhibit segregations of another kind. The flints and the nodules of iron pyrites that are found in chalk, as well as the silicious concretions which sometimes occur in limestone, are interpreted as aggregations of molecules of silex or sulphuret of iron, originally diffused through the deposit, but gradually collected round centres, notwithstanding the solid or semi-solid state of the surrounding matter. Bog iron ore supplies the conditions and the result in still more obvious correlation.

Among igneous changes we do not find so many examples of the process described. Nevertheless, geological phenomena of this order are not barren of illustrations. Where the mixed matters composing the Earth's crust have been raised to a very high temperature, segregation commonly takes place as the temperature falls. Sundry of the substances that escape in a gaseous form from volcanoes sublime into crystals on coming against cool surfaces; and solidifying, as these substances do, at different temperatures, they are deposited at different parts of the crevices through which they are emitted together. The best illustration, however, is furnished by the changes that occur during the slow cooling of igneous rock. When, through one of the fractures from time to time made in the Earth's crust, a portion of the molten nucleus is extruded, and when this is cooled with comparative rapidity, there results trap or basalt—a substance that is uniform in texture, though made up of various ingredients. But when, not escaping through the superficial strata, such a portion of the molten nucleus is slowly cooled, granite is the result: the mingled particles of quartz, feldspar, and mica, being kept for a long time in a fluid and semi-fluid state—a state of comparative mobility—undergo those changes of position which the forces impressed on them by their fellow units necessitate. The differential forces arising from mutual polarity, segregate the quartz, feldspar, and mica, into

crystals. How completely this is dependent on the long-continued agitation of the mixed particles, and consequent long-continued movableness by small differential forces, is proved by the fact that in a granite dyke the crystals in the centre, where the fluidity or semi-fluidity continued for a longer time, are much larger than those at the sides, where contact with the neighbouring rock caused more rapid cooling and solidification.

§ 166. The actions going on throughout an organism are so involved, that we cannot expect to identify the forces by which particular segregations are effected. Among the few instances admitting of interpretation, the best are those in which mechanical pressures and tensions are the agencies at work.

The spine of a vertebrate animal is subject to certain general strains—the weight of the body, together with the reactions involved by all considerable muscular efforts; and under these conditions it has become segregated as a whole. At the same time, being exposed to different forces during those lateral bendings which the movements necessitate, its parts retain a certain separateness. If we trace up the development of the vertebral column from its primitive form of a cartilaginous cord in the lowest fishes, we see that, throughout, it maintains an integration corresponding to the unity of the incident forces, joined with a division into segments corresponding to the variety of the incident forces. Each segment, considered apart, exemplifies the truth more simply. A vertebra is not a single bone, but consists of a central mass with sundry appendages or processes, and in unfinished types of vertebræ these appendages are separate from the central mass, and, indeed, exist before it makes its appearance. But these several independent bones, constituting a primitive spinal segment, are subject to a certain aggregate of forces which agree more than they differ: as the fulcrum to a group of muscles habitually acting together they perpetually undergo certain reactions in common. And accordingly, in the course of development, they gradually coalesce. Still clearer is the illustration furnished by spinal segments that become fused together where they are together exposed to some predominant strain. The sacrum consists of a group of vertebræ firmly united. In the

ostrich and its congeners there are from seventeen to twenty sacral vertebræ; and, besides being confluent with one another, these are confluent with the iliac bones, which run on each side of them. If, now, we assume these vertebræ to have been originally separate, as they still are in the embryo bird, and if we consider the forces to which they must in such case have been exposed, we shall see that their union results in the alleged way. For through these vertebræ the entire weight of the body is transferred to the legs: the legs support the pelvic arch; the pelvic arch supports the sacrum; and to the sacrum is articulated the rest of the spine, with all the organs attached to it and upheld by it. Hence, if separate, the sacral vertebræ must be held firmly together by strongly-contracted muscles, and must, by implication, be prevented from partaking in those lateral movements which the other vertebræ undergo—they must be subject to a common strain, while they are preserved from strains which would affect them differently; and so they fulfil the conditions under which segregation occurs. But the cases in which cause and effect are brought into the most obvious relation are supplied by the limbs. The metacarpal bones (those which in man support the palm of the hand) are separate from one another in most mammals: the separate actions of the toes entailing on them slight amounts of separate movements. This is not so however in the ox-tribe and the horse-tribe. In the ox-tribe, only the middle metacarpals (third and fourth) are developed; and these, attaining massive proportions, coalesce to form the cannon bone. In the horse-tribe, the segregation is what we may distinguish as indirect: the second and fourth metacarpals are present only as rudiments united to the sides of the third, while the third is immensely developed; thus forming a cannon bone which differs from that of the ox in being a single cylinder, instead of two cylinders fused together. The metatarsus in these quadrupeds exhibits parallel changes. Now each of these metamorphoses occurs where the different bones grouped together have no longer any different functions, but retain only a common function. The feet of oxen and horses are used solely for locomotion—are not put, like those of unguiculate mammals, to purposes which involve some relative movements of the metacarpals. Thus there directly or

indirectly results a single mass of bone where the incident force is single. And for the inference that these facts have a causal connexion, we find confirmation throughout the entire class of birds, in the wings and legs of which, like segregations are found under like conditions. While this sheet is passing through the press (1862), a fact illustrating this general truth in a yet more remarkable manner, has been mentioned to me by Prof. Huxley, who kindly allows me to make use of it while still unpublished by him. The *Glyptodon*, an extinct mammal found fossilized in South America, has long been known as a large uncouth creature allied to the Armadillo, but having a massive dermal armour consisting of polygonal plates closely fitted together so as to make a vast box, inclosing the body in such way as effectually to prevent it from being bent, laterally or vertically, in the slightest degree. This box, which must have weighed several hundred-weight, was supported on the spinous processes of the vertebræ, and on the adjacent bones of the pelvic and thoracic arches. And the significant fact is that here, where the trunk vertebræ were together exposed to the pressure of this heavy dermal armour, at the same time that, by its rigidity, they were preserved from all relative movements, they were united into one solid, continuous bone.

The formation and maintenance of a species, considered as an assemblage of similar organisms, is interpretable in an analogous way. Already we have seen that in so far as the members of a species are subject to different sets of incident forces, they are differentiated, or divided into varieties. Here it remains to add that such of them as are subject to like sets of incident forces, are segregated. For by the process of "natural selection," there is a continual purification of each species from those individuals which depart from the common type in ways that unfit them for the conditions of their existence. Consequently, there is a continual leaving behind of those individuals which are in all respects fit for the conditions of their existence, and are therefore nearly alike. The circumstances to which any species is exposed, being an involved combination of incident forces; and the members of the species having among them some that differ more than is usual from the average structure required for meeting these forces; it

results that these forces are constantly separating such divergent individuals from the rest, and so preserving the uniformity of the rest—keeping up its integrity as a species or variety. Just as the changing autumn leaves are picked out by the wind from among the green ones around them, or just as, to use Prof. Huxley's simile, the smaller fragments pass through a sieve while the larger are kept back; so, the uniform incidence of external forces affects the members of a group of organisms similarly in proportion as they are similar, and differently in proportion as they are different; and thus is ever segregating the like by parting the unlike from them. Whether these separated members are killed off, as mostly happens, or whether, as otherwise happens, they survive and multiply into a distinct variety, in consequence of their fitness to certain partially-unlike conditions, matters not to the argument. The one case conforms to the law that the unlike units of an aggregate are sorted into their kinds and parted, when uniformly subject to the same incident forces, and the other to the converse law that the like units of an aggregate are parted and separately grouped when subject to different incident forces. And on consulting Mr. Darwin's remarks on divergence of character, it will be seen that the segregations thus caused tend ever to become more definite.

§ 167. Mental evolution under one of its leading aspects, we found to consist in the formation in the mind of groups of like objects and like relations—a differentiation of the various things originally confounded together in one assemblage, and an integration of each separate order of things into a separate group (§ 153). Here it remains to point out that while unlikeness in the incident forces is the cause of such differentiations, likeness in the incident forces is the cause of such integrations. For what is the process through which classifications are established? How do plants become grouped in the mind of the botanist into orders, genera, and species? Each plant he examines yields him a certain complex impression. Now and then he picks up a plant like one before seen; and the recognition of it is the production in him of a like connected group of sensations by a like connected group of attributes. That is to say, there is produced throughout the nerve-

centres concerned, a combined set of changes, similar to a combined set of changes before produced. Considered analytically, each such combined set of changes is a combined set of molecular modifications wrought in the affected part of the organism. On every repetition of the impression, a like combined set of molecular modifications is superposed on the previous ones, and makes them greater: thus generating an internal plexus of modifications, with its answering idea, corresponding to these similar external objects. Meanwhile, another kind of plant produces in the brain of the botanist another set of molecular modifications—a set which does not agree with the one we have been considering, but disagrees with it; and by repetition of such there is generated a different idea answering to a different species. What, now, is the nature of this process expressed in general terms? On the one hand there are the like and unlike things from which severally emanate the groups of forces by which we perceive them. On the other hand, there are the organs of sense and percipient centres, through which, in the course of observation, these groups of forces pass. In passing through them the like groups of forces are segregated, or separated from the unlike groups of forces; and each such separate series of groups of forces, answering to an external genus or species, produces an idea of the genus or species. We before saw that as well as a separation of mixed matters by the same force, there is a separation of mixed forces by the same matter; and here we may further see that the unlike forces so separated, work unlike structural changes in the aggregate that separates them—structural changes each of which thus represents the integrated series of motions that has produced it.

By a parallel process, the relations of co-existence and sequence among impressions become sorted into kinds and grouped. When two phenomena that have been experienced in a given order are repeated in the same order, those nerve-centres which before were affected by the transition are again affected; and such molecular modification as they received from the first motion propagated through them is increased by this second motion. Each such motion works a structural alteration which, in conformity with the law set forth in Chapter IX, involves a diminished resistance to all such motions that afterwards occur. The segregation of these

successive motions (or more strictly, the permanently effective portions of them expended in overcoming resistance) thus becomes the cause of, and the measure of, the mental connexions between the impressions which the phenomena produced. Meanwhile, phenomena different from these, being phenomena that affect different nervous elements, will have their connexions severally represented by motions along other routes; and along each of these other routes, the nervous discharges will severally take place with a readiness proportionate to the frequency with which experience repeats the connexions of phenomena. The classification of relations must hence go on *pari passu* with the classification of the related things. In common with the mixed sensations received from the external world, the mixed relations it presents cannot be impressed on the organism without more or less segregation of them resulting. And through this continuous sorting and grouping of changes or motions, which constitutes nervous function, there is gradually wrought that sorting and grouping of matter, which constitutes nervous structure.

§ 168. In social evolution, the collecting together of the like and the separation of the unlike by incident forces, is primarily displayed in the same manner as we saw it to be among groups of inferior creatures. The human races tend to differentiate and integrate, as do races of other living forms.

Of the forces which effect and maintain the segregations of mankind, may first be named those external ones classed as physical conditions. The climate and food which are favourable to an indigenous people, are more or less detrimental to an alien people of different bodily constitution. In tropical regions the northern races cannot permanently exist: if not killed off in the first generation, they are so in the second, and, as in India, can maintain their footing only by the artificial process of continuous immigration and emigration. That is to say, the external forces acting equally on the inhabitants of a given locality, tend to expel all who are not of a certain type, and thus to keep up the integration of those who are of that type. Even among the Indian peoples themselves the like happens: some of the hill-tribes being segregated by surviving the malarious influences which kill off Hindus who enter

their habitat. The other forces conspiring to produce these national segregations, are those mental ones shown in the affinities of men for others like themselves. Units of one society who are obliged to reside in another, generally form colonies in the midst of that other—small societies of their own. Races which have been artificially severed, show tendencies to re-unite. Now though these segregations caused by the mutual likings of kindred men, do not seem due to the general principle enunciated, they really are thus interpretable. When treating of the direction of motion (§ 80), it was shown that the actions performed by men for the satisfaction of their wants, are always motions along lines of least resistance. The feelings characterizing a member of a given race, are feelings which get complete satisfaction only among other members of that race—a satisfaction partly derived from sympathy with those having like feelings, but mainly derived from the adapted social conditions which grow up where such feelings prevail. When, therefore, a citizen of any nation is, as we see, attracted towards others of his nation, the *rationale* is that certain agencies which we call desires move him in the direction of least resistance. Human motions, like all other motions, being determined by the distribution of forces, it follows that such segregations of races as are not produced by incident external forces are produced by forces which the units of the races exercise on one another.

During the development of each society we see analogous segregation caused in analogous ways. A few of them result from minor natural affinities; but those most important ones, which constitute political and industrial organization, result from the union of men in whom similarities have been produced by training. Men brought up to bodily labour are men who have had wrought in them a certain likeness—a likeness which, in respect of their powers of action, obscures and subordinates their natural differences. Those trained to brain-work have acquired a certain other community of character which makes them, as social units, more like one another than like those trained to manual occupations. And there arise class-segregations answering to these superinduced likenesses. More definite segregations take place among the more definitely assimilated members of any class who are brought up to the same calling. Even where the necessities of their work forbid concen-

tration in one locality, as among artizans happens with masons and bricklayers, and among traders happens with the retail distributers, and among professionals happens with the medical men, there are not wanting Operative Builders' Unions, and Grocers' Societies, and Medical Associations, implying a process of sifting out and grouping. And, where, as among the manufacturing classes, the functions discharged do not require the dispersion of citizens who are artificially assimilated, there is an aggregation of them in special localities, and a consequent increase in the definiteness of industrial divisions. If, now, we seek the causes of these segregations, considered as results of force and motion, we are brought to the same general principle as before. This likeness produced in the members of any class or sub-class by training, is an aptitude acquired by them for satisfying their wants in like ways. That is, the occupation has become to each a line of least resistance. Hence under that pressure which determines all men to activity, these similarly-modified social units are similarly affected, and tend to take similar courses. If, then, there be any locality which, either by its physical peculiarities or by peculiarities wrought on it during social evolution, is rendered a place where a certain kind of industrial action meets with less resistance than elsewhere, it follows from the law of direction of motion that those social units who have been moulded to this kind of industrial action, will be segregated by moving towards this place. If, for instance, the proximity of coal and iron mines to a navigable river, gives to Glasgow an advantage in the building of iron-ships—if the total labour required to produce a given vessel, and get its equivalent in food and clothing, is less there than elsewhere; there is caused a concentration of iron-ship builders at Glasgow, either by detention of the population born to iron-ship building, or by immigration of those elsewhere engaged in it, or by both. The principle equally holds where the occupation is mercantile instead of manufacturing. Stock-brokers cluster where the amount of effort to be severally gone through by them in discharging their functions, and obtaining their profits, is less than elsewhere. A local exchange having once been established, becomes a place where the resistance to be overcome by each is smaller than in any other place; and, being like units under stress of common desires, pursuit of the

course of least resistance by each involves their aggregation around this place.

Of course, with units so complex as those which constitute a society, and with forces so involved as those which move them, the resulting selections and separations must be far more entangled, or far less definite, than those we have hitherto considered. For men's likenesses being of various kinds, lead to various orders of segregation. There are likenesses of disposition, likenesses of taste, likenesses produced by education, likenesses that result from class-habits, likenesses of political feeling; and it needs but to glance round at the caste divisions, the associations for philanthropic, scientific, and artistic purposes, the religious parties and social cliques, to see that some species of likeness among the component members of each body determines their union. Now the different segregative processes, by traversing one another and often by their indirect antagonism, more or less obscure one another's effects, and prevent any one differentiated class from completely integrating. But if this cause of incompleteness be borne in mind, social segregations will be seen to conform to the same principle as all other segregations.

§ 169. Can the general truth thus variously illustrated be deduced from the persistence of force, in common with foregoing truths? Probably the exposition at the beginning of the chapter will have led most readers to conclude that it can be so deduced.

The abstract propositions involved are these:—First, that like units, subject to a uniform force capable of producing motions in them, will be moved to like degrees in the same direction. Second, that like units if exposed to unlike forces capable of producing motion in them, will be differently moved—moved either in different directions or to different degrees in the same direction. Third, that unlike units if acted on by a uniform force capable of producing motion in them, will be differently moved—moved either in different directions or to different degrees in the same direction. Fourth, that the incident forces themselves must be affected in analogous ways: like forces falling on like units must be similarly modified by the conflict; unlike forces falling on like units must be dissimilarly modified; and like forces falling on

unlike units must be dissimilarly modified. These propositions may be reduced to a still more abstract form. They all imply that in the actions and reactions of force and matter, an unlikeness in either of the factors necessitates an unlikeness in the effects, and that in the absence of unlikeness in either of the factors the effects must be alike.

When they are thus generalized, the dependence of these propositions on the persistence of force is obvious. Any two forces that are not alike, are forces which differ either in their amounts or directions or both; and by what is called the resolution of forces, it may be proved that this difference is constituted by the presence in the one of some force not present in the other. Similarly, any two units or portions of matter which are unlike in size, form, weight, or other attribute, can be known as unlike only through some unlikeness in the forces they impress on us; and hence this unlikeness also, is constituted by the presence in the one of some force or forces not present in the other. Such being the common nature of these unlikenesses, what is the corollary? Any unlikeness in the incident forces, where the things acted on are alike, must generate a difference between the effects; since, otherwise, the differential force produces no effect, and force is not persistent. Any unlikeness in the things acted on, where the incident forces are alike, must generate a difference between the effects; since, otherwise, the differential force whereby these things are made unlike, produces no effect, and force is not persistent. While, conversely, if the forces acting and the things acted on are alike, the effects must be alike; since, otherwise, a differential effect can be produced without a differential cause, and force is not persistent.

Thus these general truths being necessary implications of the persistence of force, all the re-distributions above traced out as characterizing Evolution in its various phases, are also implications of the persistence of force. If, of the mixed units making up any aggregate, those of the same kind have like motions impressed on them by a uniform force, while units of another kind are moved by this uniform force in ways more or less unlike the ways in which those of the first kind are moved, the two kinds must separate and integrate. If the units are alike and the forces unlike, a division

of the differently affected units is equally necessitated. Thus there inevitably arises the demarcated grouping which we everywhere see. By virtue of this segregation, growing ever more decided while there remains any possibility of increasing it, the change from uniformity to multiformity is accompanied by a change from indistinctness in the relations of parts to distinctness in the relations of parts. As we before saw that the transformation of the homogeneous into the heterogeneous is inferable from that ultimate truth which transcends proof; so we here see that from this same truth is inferable the transformation of an indefinite homogeneity into a definite heterogeneity.

## CHAPTER XXII

### EQUILIBRATION

§ 170. Towards what do these changes tend? Will they go on for ever? or will there be an end to them? Can things increase in heterogeneity through all future time? or must there be a degree which the differentiation and integration of Matter and Motion cannot pass? Is it possible for this universal metamorphosis to proceed in the same general course indefinitely? or does it work towards some ultimate state admitting no further modification of like kind? The last of these alternative conclusions is that to which we are inevitably driven. Whether we watch concrete processes, or whether we consider the question in the abstract, we are alike taught that Evolution has an impassable limit.

The re-distributions of matter which go on around us are ever being brought to conclusions by the dissipation of the motions which effect them. The rolling stone parts with portions of its momentum to the things it strikes, and finally comes to rest; as do also, in like manner, the various things it has struck. Descending from the clouds and trickling over the Earth's surface till it gathers into brooks and rivers, water, still running towards a lower level, is at last arrested by the resistance of other water that has reached the lowest level. In the lake or sea thus formed, every agitation raised by a wind or the immersion of a solid body, propagates itself around in waves which diminish as they widen, and gradually become lost to observation in motions communicated to the atmosphere and the matter on the shores. The impulse given by a player to a harp-string is transformed through its vibrations into aërial pulses; and these, spreading on all sides, and weakening as they spread, soon cease to be perceptible, and are

gradually expended in generating thermal undulations that radiate into space: each aërial pulse causing compression and evolution of heat. Equally in the cinder which falls out of the fire, and in the vast mass of molten lava ejected by a volcano, we see that the molecular agitation disperses itself by radiation; so that the temperature inevitably sinks at last to the same degree as that of surrounding bodies. The proximate *rationale* of the process exhibited under these several forms, lies in the fact dwelt on when treating of the Multiplication of Effects, that motions are ever being decomposed into divergent motions, and these into re-divergent motions. The rolling stone sends off the stones it hits in directions differing more or less from its own, and they do the like with the things they hit. Move water or air, and the movement is quickly resolved into dispersed movements. The heat produced by pressure in a given direction diffuses itself by undulations in all directions. That is to say, these motions undergo division and subdivision, and by continuance of this process without limit they are, though never lost, gradually dissipated.

In all cases, then, there is a progress toward equilibrium. That universal co-existence of antagonist forces which, as we before saw, necessitates the universality of rhythm, and which, as we before saw, necessitates the decomposition of every force into divergent forces, at the same time necessitates the ultimate establishment of a balance. Every motion, being motion under resistance, is continually suffering deductions; and these unceasing deductions finally result in the cessation of the motion.

The general truth thus illustrated under its simplest aspect, we must now look at under those more complex aspects it usually presents throughout Nature. In nearly all cases, the motion of an aggregate is compound; and the equilibration of each of its components, being carried on independently, does not affect the rest. The ship's bell that has ceased to vibrate, still continues those vertical and lateral oscillations caused by the ocean-swell. The water of a smooth stream on whose surface have died away the undulations caused by a rising fish, moves as fast as before towards the sea. The arrested bullet travels with undiminished speed round the Earth's axis. And were the rotation of the Earth destroyed, there would not be implied any diminution of the Earth's move-

ment with respect to the Sun and other external bodies. So that in every case, what we regard as equilibration is the disappearance of some one or more of the many movements a body possesses, while its other movements continue as before. That this process may be duly realized and the state of things towards which it tends fully understood, it will be well here to cite a case in which we may watch this successive equilibration of combined movements more completely than we can do in those above instanced. Our end will best be served not by the most imposing but by the most familiar example. Let us take that of a spinning top. When the string which has been wrapped round a top's axis is violently drawn off, and the top falls on to the table, it usually happens that besides the rapid rotation two other movements are given to it. A slight horizontal momentum, unavoidably impressed on it when leaving the handle, carries it away bodily from the place on which it drops; and in consequence of its axis being more or less inclined, it falls into a certain oscillation, described by the expressive though inelegant word "wabbling." These two subordinate motions, variable in their proportions to each other and to the chief motion, are commonly soon brought to a close by separate processes of equilibration. The momentum which carries the top bodily along the table, resisted somewhat by the air but mainly by the irregularities of the surface, shortly disappears; and the top thereafter continues to spin on one spot. Meanwhile, in consequence of that opposition which the axial momentum of a rotating body makes to any change in the plane of rotation, (so beautifully exhibited by the gyroscope,) the "wabbling" diminishes, and like the other is quickly ended. These minor motions having been dissipated, the rotatory motion, interfered with only by atmospheric resistance and the friction of the pivot, continues some time with such uniformity that the top appears stationary: there being thus temporarily established a condition which the French mathematicians have termed *equilibrium mobile*. It is true that when the velocity of rotation sinks below a certain point, new motions commence and increase till the top falls; but these are merely incidental to a case in which the centre of gravity is above the point of support. Were the top, having an axis of steel, to be suspended from a surface adequately magnetized,

the moving equilibrium would continue until the top became motionless, without any further change of attitude. Now the facts which it behoves us here to observe are these. First, that the various motions which an aggregate possesses are separately equilibrated: those which are smallest, or which meet with the greatest resistance, or both, disappearing first; and leaving at last that which is greatest, or meets with least resistance, or both. Second, that when the aggregate has a movement of its parts with respect to each other which encounters but little external resistance, there is apt to be established a moving equilibrium. Third, that this moving equilibrium eventually lapses into complete equilibrium.

Fully to comprehend the process of equilibration, is not easy; since we have simultaneously to contemplate various phases of it. The best course will be to glance separately at what we may conveniently regard as its four different orders. The first order includes the comparatively simple motions, as those of projectiles, which are not prolonged enough to exhibit their rhythmical character, but which, being quickly divided and subdivided into motions communicated to other portions of matter, are presently dissipated in the rhythm of ethereal undulations. In the second order, comprehending various kinds of ordinary vibration or oscillation, the implied energy is used up in generating a tension which, having become equal to it or momentarily equilibrated with it, thereupon produces a motion in the opposite direction that is subsequently equilibrated in like manner: thus causing a visible rhythm which is presently lost in invisible rhythms. The third order of equilibration, not hitherto noticed, obtains in those aggregates which continually receive as much energy as they expend. The steam-engine (and especially that kind which feeds its own furnace and boiler) supplies an example. Here the energy from moment to moment dissipated in overcoming the resistance of the machinery driven, is from moment to moment re-placed from the fuel; and the balance of the two is maintained by a raising or lowering of the expenditure according to the variation of the supply: each increase or decrease in the quantity of steam, resulting in a rise or fall of the engine's movement, such as brings it to a balance with the increased or decreased resistance. This, which

we may fitly call the *dependent* moving equilibrium, should be specially noted; since it is one that we shall commonly meet with throughout various phases of Evolution. The equilibration to be distinguished as of the fourth order, is the *independent* or perfect moving equilibrium. This we see illustrated in the rhythmical motions of the Solar System, which, being resisted only by a medium of inappreciable density, undergo no sensible diminution in such periods of time as we can measure.

Something has still to be added. The reader must note two leading truths brought out by the foregoing exposition: the one concerning the ultimate, or rather the penultimate, state of motion which the processes described tend to bring about; the other concerning the concomitant distribution of matter. This penultimate state of motion is the moving equilibrium, which tends to arise in an aggregate having compound motions, as a transitional state on the way towards complete equilibrium. Throughout Evolution of all kinds there is a continual approximation to, and more or less complete maintenance of, this moving equilibrium. As in the Solar System there has been established an independent moving equilibrium — an equilibrium such that the relative motions of its members are continually so counterbalanced by opposite motions that the mean state of the aggregate never varies; so is it, though in a less distinct manner, with each form of dependent moving equilibrium. The state of things exhibited in the cycles of terrestrial changes, in the balanced functions of organic bodies that have reached their adult forms, and in the acting and re-acting processes of fully-developed societies, is similarly one characterized by compensating oscillations. The involved combination of rhythms seen in each of these cases, has an average condition which remains practically constant during the deviations ever taking place on opposite sides of it. And the fact which we have here to observe is that, as a corollary from the general law of equilibration, every evolving aggregate must go on changing until a moving equilibrium is established; since, as we have seen, an excess of force which the aggregate possesses in any direction must eventually be expended in overcoming resistances to change in that direction: leaving behind only those movements which compensate one another, and so form a moving

equilibrium. Respecting the structural state simultaneously reached, it must obviously be one presenting an arrangement of forces that counterbalance all the forces to which the aggregate is subject. So long as there remains a residual force in any direction—be it excess of a force exercised by the aggregate on its environment, or of a force exercised by its environment on the aggregate, equilibrium does not exist; and therefore the re-distribution of matter must continue. Whence it follows that the limit of heterogeneity towards which every aggregate progresses is the formation of as many specializations and combinations of parts as there are specialized and combined forces to be met.

§ 171. Those successively changed forms which, if the nebular hypothesis be granted, must have arisen during the evolution of the Solar System, were so many transitional kinds of moving equilibrium, severally giving place to more enduring kinds. Thus the assumption of an oblate spheroidal figure by condensing nebulous matter was the assumption of a temporary and partial moving equilibrium among the component parts—a moving equilibrium that must have grown more settled as local conflicting movements were dissipated. In the formation and detachment of the nebulous rings which, according to this hypothesis, from time to time took place, we have instances of progressive equilibration severally ending in the establishment of a complete moving equilibrium. For the genesis of each such ring implies a balancing of that attractive force which the whole spheroid exercises on its equatorial portion, by that centrifugal force which the equatorial portion has acquired during previous concentration. So long as these two forces are not equal, the equatorial portion follows the contracting mass; but as soon as the second force has increased up to an equality with the first, the equatorial portion can follow no further and remains behind. While, however, the resulting ring, regarded as a whole, has reached a state of moving equilibrium, its parts are not balanced with respect to one another. As we before saw (§ 150) the probabilities against the maintenance of an annular form by nebulous matter, are great: from the instability of the homogeneous, it is inferable that nebulous matter so distributed will break up into portions, and eventually concentrate

into a single mass. That is to say, the ring will progress towards a moving equilibrium of a more complete kind, during the dissipation of that motion which maintained its particles in a diffused form; leaving at length a planetary body attended perhaps by a group of minor bodies similarly produced, constituting a moving equilibrium that is all but perfect.*

Hypothesis aside, the principle of equilibration is still perpetually illustrated in those minor changes of state which the Solar System undergoes. Each planet, satellite, and comet, exhibits at its aphelion a momentary equilibrium between that force which urges it further away from its primary, and that force which retards its retreat. In like manner at perihelion a converse equilibrium is momentarily established. The variation of each orbit in eccentricity, and in the position of its plane, has similarly a limit at which the forces producing change in the one direction, are equalled by those antagonizing it; and an opposite limit at which an opposite arrest takes place. Meanwhile, each of these simple perturbations, as well as each of the complex ones resulting from their combination, exhibits, besides the temporary equilibration at each of its extremes, a certain general equilibration of compensating deviations on either side of a mean state. That the moving equilibrium thus constituted tends, in the course of indefinite time, to lapse into a complete equilibrium, by the gradual decrease of planetary motions and

* Sir David Brewster has cited with approval, a calculation by M. Babinet, to the effect that on the hypothesis of nebular genesis, the matter of the Sun, when it filled the Earth's orbit, must have taken 3181 years to rotate; and that therefore the hypothesis cannot be true. This calculation of M. Babinet may pair off with that of M. Comte who, contrariwise, made the time of this rotation agree very nearly with the Earth's period of revolution round the Sun. For if M. Comte's calculation involved a *petitio principii*, that of M. Babinet is based on two assumptions both of which are gratuitous, and one of them inconsistent with the doctrine to be tested. He has evidently proceeded on the current supposition respecting the Sun's internal density, which is not proved, and from which there are reasons for dissenting; and he has evidently taken for granted that all parts of the nebulous spheroid, when it filled the Earth's orbit, had the same angular velocity; whereas if (as is implied in the nebular hypothesis, rationally understood) this spheroid resulted from the concentration of widely-diffused matter, the angular velocity of its equatorial portion would obviously be far greater than that of its central portion

eventual integration of all the separate masses composing the Solar System, is a belief suggested by certain observed cometary retardations—a belief entertained by some of high authority. The received opinion that the appreciable diminution in the period of Encke's comet, implies a loss of momentum caused by resistance of the ethereal medium, commits astronomers who hold it to the conclusion that this same resistance must cause a loss of planetary motions—a loss which, infinitesimal though it may be in such periods as we can measure, will, if indefinitely continued, bring these motions to a close. Even should there be, as Sir John Herschel suggests, a rotation of the ethereal medium in the same direction with the planets, this arrest, though immensely postponed, would not be absolutely prevented. Such an eventuality, however, must in any case be so inconceivably remote as to have no other than a speculative interest for us. It is referred to here, simply as illustrating the still-continued tendency towards complete equilibrium, through the still-continued dissipation of sensible motion, or transformation of it into insensible motion.

But there is another species of equilibration going on in the Solar System, with which the human race is less remotely concerned. The tacit assumption that the Sun can continue to give off an undiminished amount of light and heat through all future time is now abandoned. Involving as it does, under a disguise, the conception of power produced out of nothing, it is of the same order as the belief which misleads perpetual-motion schemers. The spreading recognition of the truth that whatever force is manifested under one shape must previously have existed under another shape, implies recognition of the truth that the force known to us in solar radiations, is the changed form of some other force of which the Sun is the seat; and that, by the emission of these radiations, this other force is being slowly exhausted. The force by which the Sun's substance is drawn to his centre of gravity, is the only one which physical laws warrant us in concluding to be the correlate of the forces emanating from him: the only assignable source for the insensible motions constituting solar light and heat, is the sensible motion which disappears during the concentration of the Sun's mass. We before

saw it to be a corollary from the nebular hypothesis, that there *is* such a progressing concentration of the Sun's mass. And here remains to be added the further corollary, that just as in the case of the small members of the Solar System, the heat generated by concentration, once escaping rapidly, has in each left a central residue which escapes but slowly; so in the case of that immensely larger mass forming the Sun, the immensely greater quantity of heat generated and still in process of rapid diffusion, must, as the concentration approaches its limit, diminish in amount, and eventually leave but a relatively small internal remnant. With or without the accompaniment of that hypothesis of nebular condensation whence it naturally follows, the doctrine that the Sun is gradually losing his heat, has now gained general acceptance; and calculations have been made, both respecting the amount of heat and light already radiated, as compared with the amount that remains, and respecting the period during which active radiation will continue. Prof. Helmholtz estimates that since the time when, according to the nebular hypothesis, the matter composing the Solar System extended to the orbit of Neptune, there has been evolved by the arrest of sensible motion, an amount of heat 454 times as great as that which the Sun still has to give out. He also makes an approximate estimate of the rate at which this remaining $\frac{1}{454}$th is being diffused: showing that a decrease of the Sun's diameter to the extent of $\frac{1}{10,000}$, would produce heat, at the present rate, for more than 2000 years; or in other words, that a contraction of $\frac{1}{20,000,000}$ of his diameter, suffices to generate the light and heat annually emitted; and that thus, at the present rate of expenditure, the Sun's diameter will diminish by something like $\frac{1}{20}$ in the lapse of the next million years.* Of course these conclusions are but rude approximations to the truth. Until quite recently, we have been totally ignorant of the Sun's chemical composition, and even now have obtained but a superficial knowledge of it. We know nothing of his internal structure; and it is quite possible that the assumptions respecting central density, made in the foregoing estimates, are wrong. But

* See paper "On the Inter-action of Natural Forces," by Prof. Helmholtz, translated by Prof. Tyndall, and published in the *Philosophical Magazine*, supplement to Vol. XI., fourth series.

no uncertainty in the data on which these calculations proceed, and no consequent error in the inferred rate at which the Sun is expending his reserve of energy, militates against the general proposition that this reserve of energy *is* being expended, and must in time be exhausted.

Thus while the Solar System, if evolved from diffused matter, has illustrated the law of equilibration in the establishment of a moving equilibrium; and while, as at present constituted, it illustrates the law of equilibration in the perpetual balancing of all its movements; it also illustrates this law in these processes which astronomers and physicists infer are still going on. That motion of masses produced during Evolution, is being slowly re-diffused in molecular motion of the ethereal medium; both through the progressive integration of each mass, and the resistance to its motion through space. Infinitely remote as may be the state when all the relative motions of its masses shall be transformed into molecular motion, and all the molecular motion dissipated; yet such a state of complete integration and complete equilibration, is that towards which the changes now going on throughout the Solar System inevitably tend.

§ 172. A spherical figure is the one which can alone equilibrate the forces of mutually-gravitating molecules. If an aggregate of such molecules rotates, the form of equilibrium becomes a spheroid of greater or less oblateness, according to the rate of rotation; and it has been ascertained that the Earth is an oblate spheroid, diverging just as much from sphericity as is requisite to counterbalance the centrifugal force consequent on its velocity round its axis. That is to say, during the evolution of the Earth, there has been reached an equilibrium of those forces which affect its general outline. The only other equilibration which the Earth as a whole can exhibit is the loss of its rotation; and that any such loss is going on we have no direct evidence. It has been contended, however, by Prof. Helmholtz and others, that inappreciable as may be its effect within known periods of time, the friction of the tidal wave must be diminishing the Earth's motion round its axis, and must eventually destroy it. Now though it seems an oversight to say that the axial motion can thus be destroyed, since the extreme

effect, to be reached only in infinite time, would be an extension of the Earth's day to the length of lunation; yet it seems clear that this friction of the tidal wave is a real cause of decreasing rotation. Slow as its action is, we must recognize its retarding effect as exemplifying, under another form, the universal progress towards equilibrium.*

It is needless to show in detail how those movements which the Sun's rays generate in the air and water on the Earth's surface, and through them in the Earth's solid substance,† one and all teach the same general truth. Evidently the winds and waves and streams, as well as the denudations and depositions they effect, illustrate on a grand scale, and in endless modes, that gradual dissipation of motions described in the first section, and the consequent tendency towards a balanced distribution of forces. Each of these sensible motions, produced directly or indirectly by integration of those insensible motions communicated from the Sun, becomes divided and subdivided into motions less and less sensible; until by gradual or sudden arrest of each, and production of its equivalent in molecular motion, there is an escape of it into space in the shape of thermal undulations. In their totality, these complex motions constitute a dependent moving equilibrium. As we before saw there is traceable throughout them an involved combination of rhythms. The unceasing circulation of water from the ocean to the land and from the land back to the ocean, is a type of these various compensating actions which, in the midst of all the irregularities produced by their mutual interferences, maintain an average. And in this, as in other equilibrations of the third order, we see that the energy ever in course of dissipation, is ever renewed from without: the rises and falls in the supply being

* While the effect of tidal friction is to decrease the rate of rotation, the still-continued contraction of the Earth has the effect of increasing it. How the difference between these conflicting effects is to be ascertained it is not easy to see.

† Until I recently consulted his *Outlines of Astronomy* on another question, I was not aware that so far back as 1833, Sir John Herschel had pointed out that "the sun's rays are the ultimate source of almost every motion which takes place on the surface of the earth." He expressly includes geologic, meteorologic, and vital actions; as also those which we produce by the combustion of coal.

balanced by rises and falls in the expenditure; as witness the variations of meteorologic activity in northern zones caused by changes of the seasons. But the fact it chiefly concerns us to note is that this process must go on bringing things ever nearer to complete rest. These mechanical movements, meteorologic and geologic, which are continually being equilibrated, both temporarily by counter-movements and permanently by the dissipation of such movements and counter-movements, will slowly diminish as the quantity of force received from the Sun diminishes. As the insensible motions propagated to us from the centre of our system become feebler, the sensible motions here produced by them must decrease; and at that remote period when the solar heat has ceased to be appreciable, there will no longer be any appreciable re-distributions of matter on the surface of our planet.

Thus, all terrestrial changes are incidents in the course of cosmical equilibration. It was before pointed out (§ 69), that of the incessant alterations which the Earth's crust and atmosphere undergo, those which are not due to the action of the moon and to the still-progressing motion of the Earth's substance towards its centre of gravity, are due to the still-progressing motion of the Sun's substance towards its centre of gravity. Here it is to be remarked that this continuance of integration in the Earth and in the Sun is a continuance of that transformation of sensible motion into insensible motion which we have seen ends in equilibrium; and that the arrival in each case at the extreme of integration, is the arrival at a state in which no more sensible motion remains to be transformed into insensible motion—a state in which the forces producing integration and the forces opposing integration have become equal.

§ 173. Every living body exhibits, in a four-fold form, the process we are tracing out—exhibits it from moment to moment in the balancing of mechanical forces; from hour to hour in the balancing of functions; from year to year in the changes of state that compensate changes of conditions; and finally in the arrest of vital movements at death. Let us consider the facts under these heads.

The sensible motion constituting each visible action of an animal

is soon brought to a close by some opposing force within or without the animal. When a man's arm is raised, the motion given to it is antagonized partly by gravity and partly by the internal resistances consequent on structure; and its motion, thus suffering continual deduction, ends when the arm has reached a position at which the forces are equilibrated. The limits of each systole and diastole of the heart severally show us a momentary equilibrium between muscular strains that produce opposite movements; and each gush of blood has to be immediately followed by another, because the rapid dissipation of its momentum would otherwise soon bring the circulating mass to a stand. As much in the actions and reactions going on among the internal organs, as in the mechanical balancing of the whole body, there is at every instant a progressive equilibration of the motions at every instant produced. Viewed in their aggregate, and as forming a series, the organic functions constitute a dependent moving equilibrium—a moving equilibrium of which the motive power is ever being dissipated through the special equilibrations just exemplified, and is ever being renewed by the taking in of additional motive power. The force stored up in food continually adds to the momentum of the vital actions, as much as is continually deducted from them by the forces overcome. All the functional movements thus maintained are rhythmical (§ 85); by their union compound rhythms of various lengths and complexities are produced; and in these simple and compound rhythms, the process of equilibration, besides being exemplified at each extreme of every rhythm, is seen in the habitual preservation of a constant mean, and in the re-establishment of that mean when accidental causes have produced divergence from it. When, for instance, there is a great expenditure of muscular energy, there arises a reactive demand on those stores of energy which are laid up in the form of consumable matter throughout the tissues: increased respiration and increased circulation aid an extra genesis of force, that counterbalances the extra dissipation of force. This unusual transformation of molecular motion into sensible motion is presently followed by an unusual absorption of food—the source of molecular motion; and the prolonged draft on the spare capital in the tissues is followed by a prolonged rest, during which the abstracted

capital is replaced. If the deviation from the ordinary course of the functions has been so great as to derange them, as when violent exertion produces loss of appetite and loss of sleep, an equilibration is still eventually effected. Providing the disturbance is not such as to destroy life (in which case complete equilibration is suddenly effected), the ordinary balance is by and by re-established: the returning appetite is keen in proportion as the waste has been large; while sleep, sound and prolonged, makes up for previous wakefulness. Not even when some extreme excess has wrought a derangement that is never wholly rectified is there an exception to the general law; for in such cases the cycle of the functions is, after a time, equilibrated about a new mean state, which thenceforth becomes the normal state of the individual. And this process exemplifies in a large way what physicians call the *vis medicatrix naturæ*. The third form of equilibration displayed by organic bodies, is a sequence of that just illustrated. When, through a change of habit or circumstance, an organism is permanently subject to some new influence, or different amount of an old influence, there arises, after more or less disturbance of the organic rhythms, a balancing of them around the new average condition produced by this additional influence. If the quantity of motion to be habitually generated by a muscle becomes greater than before, its nutrition becomes greater than before. If the expenditure of the muscle bears to its nutrition a greater ratio than expenditure bears to nutrition in other parts of the system, the excess of nutrition becomes such that the muscle grows. And the cessation of its growth is the establishment of a balance between the daily waste and the daily repair. The like is manifestly the case with all organic modifications consequent on changes of climate or food. If we see that a different mode of life is followed, after a period of derangement, by some altered condition of the system—if we see that this altered condition, becoming by and by established, continues without further change; we have no alternative but to say that the new forces brought to bear on the system, have been compensated by the opposing forces they have evoked. And this is the interpretation of the process called *adaptation*. Finally, each organism illustrates the law in the *ensemble* of its life. At the outset it daily absorbs, under the

form of food, an amount of force greater than it daily expends; and the surplus is daily equilibrated by growth. As maturity is approached this surplus diminishes; and in the perfect organism the day's absorption of latent energy balances the day's expenditure of actual energy. That is to say, during adult life there is continuously exhibited an equilibrium of the third order. Eventually, the daily loss begins to outbalance the daily gain, and there results a diminishing amount of functional action; the organic rhythms extend less and less widely on each side of the medium state; and there finally comes that complete equilibrium we call death.

The ultimate structural state accompanying that ultimate functional state towards which an organism tends may be deduced from one of the propositions set down in the opening section of this chapter. We saw that the limit of heterogeneity is reached when the equilibration of any aggregate becomes complete—that the re-distribution of matter can continue so long only as there continues some motion unbalanced. What is the implication in the case of organic aggregates? We have seen that to maintain the moving equilibrium of one, requires the habitual genesis of internal forces corresponding in number, directions, and amounts to the external incident forces—as many inner functions, single or combined, as there are single or combined outer actions to be met. But functions are the correlatives of organs; amounts of functions are, other things equal, the correlatives of sizes of organs; and combinations of functions the correlatives of connexions of organs. Hence the structural complexity accompanying functional equilibrium is definable as one in which there are as many specialized parts as are capable, separately and jointly, of counteracting the separate and joint forces amid which the organism exists. And this is the limit of organic heterogeneity; to which Man has approached more nearly than any other creature.

Groups of organisms display this universal tendency towards a balance very obviously. In § 85, every species of plant and animal was shown to be perpetually undergoing a rhythmical variation in number—now from abundance of food or absence of enemies rising above its average; and then, by a consequent scarcity of food or abundance of enemies, being depressed below its

average. And here we have to observe that there is thus maintained an equilibrium between the sum of those forces which result in the increase of each race, and the sum of those forces which result in its decrease. Either limit of variation is a point at which the one set of forces, before in excess of the other, is counterbalanced by it. And amid these oscillations, produced by their conflict, lies that average number of the species at which its expansive tendency is in equilibrium with surrounding repressive tendencies. Nor can it be questioned that this balancing of the preservative and destructive forces which we see going on in every race must necessarily go on. Increase of number cannot but continue until increase of mortality stops it; and decrease of number cannot but continue until it is either arrested by fertility or extinguishes the race entirely.

§ 174. The equilibrations of those nervous actions, which constitute the obverse face of mental life, may be classified in like manner with those which constitute what we distinguish as bodily life. We may deal with them in the same order.

Each pulse of nerve force from moment to moment generated, (and it was explained in § 86 that nerve currents are not continuous but rhythmical,) is met by counteracting forces, in overcoming which it is dispersed and equilibrated. Such part of it as does not work mental changes works bodily changes—contractions of the involuntary muscles, the voluntary muscles, or both; as also some stimulation of secreting organs. That the movements thus initiated are ever being brought to a close by the opposing forces they evoke, we have just seen; and here it is to be observed that the like holds with the cerebral changes thus initiated. The arousing of a thought or feeling involves the overcoming of a certain resistance: instance the fact that, where the association of mental states has not been frequent, a sensible effort is needed to call up the one after the other; instance the fact that during nervous prostration there is a comparative inability to think—the ideas will not follow one another with the ordinary rapidity; instance the converse fact that at times of unusual energy, natural or artificial, thinking is easy, and more numerous, more remote, or more difficult connexions of ideas are

formed. That is to say, the wave of nervous energy each instant generated propagates itself throughout body and brain, along those channels which the passing conditions render lines of least resistance; and, spreading widely in proportion to its amount, ends only when it is equilibrated by the resistances it everywhere meets. If we contemplate mental actions as extending over hours and days, we discover equilibrations analogous to those hourly and daily established among the bodily functions. This is seen in the daily alternation of mental activity and mental rest—the forces expended during the one being compensated by the forces acquired during the other. It is also seen in the recurring rise and fall of each desire. Each desire reaching a certain intensity is equilibrated either by expenditure of the energy it embodies in the desired actions, or, less completely, in the imagination of such actions: the process ending in that satiety, or that comparative quiescence, forming the opposite limit of the rhythm. And it is further manifest under a two-fold form on occasions of intense joy or grief. Each paroxysm, expressing itself in violent actions and loud sounds, presently reaches an extreme whence the counteracting forces produce return to a condition of moderate excitement; and the successive paroxysms, finally diminishing in intensity, end in a mental equilibrium either like that before existing, or having a partially different medium state. But the kind of mental equilibration to be especially noted, is that shown in the establishment of a correspondence between relations among our ideas and relations in the external world. Each outer connexion of phenomena which we are capable of perceiving, generates, through accumulated experiences, an inner connexion of mental states; and the result towards which this process tends is the formation of a mental connexion having a relative strength that answers to the relative constancy of the physical connexion represented. In conformity with the general law that motion pursues the line of least resistance, and that, other things equal, a line once taken by motion is made a line which will be more readily taken by future motion, we have seen that the ease with which nervous impressions follow one another is, other things equal, great in proportion to the number of times they have been repeated together in experience. Hence, corresponding to such an invariable

relation as that between the resistance of an object and some extension possessed by it, there arises an indissoluble connexion in consciousness; and this connexion, being as absolute internally as the answering one is externally, undergoes no further change—the inner relation is in perfect equilibrium with the outer relation. Conversely, it happens that, answering to such uncertain relations of phenomena as that between clouds and rain, there arise relations of ideas of like uncertainty; and if, under given aspects of the sky, the tendencies to infer fair or foul weather correspond to the frequencies with which fair or foul weather follows such aspects, the accumulation of experiences has balanced the mental sequences and the physical sequences. When it is remembered that between these extremes there are countless orders of external associations having different degrees of constancy, and that during the evolution of intelligence there arise answering internal associations having different degrees of cohesion; it will be seen that there is a progress towards equilibrium between the relations of thought and the relations of things. The like general truths are exhibited in the process of moral adaptation, which is a continual approach to equilibrium between the emotions and the kinds of conduct required by surrounding conditions. Just as repeating the association of two ideas facilitates the excitement of the one by the other, so does each discharge of feeling into action render the subsequent discharge of such feeling into such action more easy. Thus it happens that if an individual is placed permanently in conditions which demand more action of a special kind than has before been requisite, or than is natural to him—if by every more frequent or more lengthened performance of it under such pressure the resistance is somewhat diminished; then, clearly, there is an advance towards a balance between the demand for this kind of action and the supply of it. Either in himself, or in his descendants continuing to live under these conditions, enforced repetition must at length bring about a state in which this mode of directing the energies will be no more repugnant than the other modes previously natural to the race. Hence the limit towards which emotional modification perpetually tends, is a combination of desires that correspond to the various orders of activity which the circumstances of life call for. In acquired habits, and

in the moral differences of races and nations that are produced by habits maintained through successive generations, we have illustrations of this progressive adaptation, which can cease only with the establishment of equilibrium between constitution and conditions.

§ 175. Each society displays the process of equilibration in the continuous adjustment of its population to its means of subsistence. A tribe of men living on wild animals and fruits, is manifestly, like every tribe of inferior creatures, always oscilliating from side to side of that average number which the locality can support. Though, by artificial production unceasingly improved, a superior race continually alters the limit which external conditions put to population; yet there is ever a checking of population at the temporary limit reached. It is true that where the limit is being rapidly changed, as among ourselves, there is no actual stoppage: there is only a rhythmical variation in the rate of increase. But in noting the causes of this rhythmical variation—in watching how, during periods of abundance, the proportion of marriages increases, and how it decreases during periods of scarcity, it will be seen that the expansive force produces unusual advance whenever the repressive force diminishes, and *vice versâ;* and thus there is as near a balancing of the two as the changing conditions permit.

The internal actions constituting social functions, exemplify the general principle no less clearly. Supply and demand are continually being adjusted throughout all industrial processes; and this equilibration is interpretable in the same way as preceding ones. The production and distribution of a commodity imply a certain aggregate of forces causing special kinds and amounts of motion. The price of this commodity is the measure of a certain other aggregate of forces expended in other kinds and amounts of motion by the labourer who purchases it. And the variations of price represent a rhythmical balancing of these forces. Every rise or fall in the value of a particular security, implies a conflict of forces in which some, becoming temporarily predominant, cause a movement that is presently arrested, or equilibrated, by the increased opposing forces; and amid these daily and hourly oscillations lies a more slowly-varying medium, into which the value ever

tends to settle, and would settle but for the constant addition of new influences. As in the individual organism so in the social organism, functional equilibrations generate structural equilibrations. When on the workers in any trade there comes an increased demand, and when in return for the increased supply they receive an amount of other commodities larger than before—when, consequently, the resistances overcome by them in sustaining life are less than the resistances overcome by other workers; there results a flow of other workers into this trade. This flow continues until the extra demand is met, and the wages so far fall that the total resistance overcome in obtaining a livelihood is as great in this newly-adopted occupation as in the occupations whence it drew recruits. The occurrence of motion along lines of least resistance was before shown to necessitate the growth of population in those places where the labour required for self-maintenance is the smallest; and here we further see that those engaged in any such advantageous locality must multiply till there arises an approximate balance between its population and that of others available by the same citizens.

These various industrial actions and reactions constitute a dependent moving equilibrium like that maintained among the functions of an individual organism, and like it tends ever to become more complele. During early stages of social evolution, while the resources of the locality inhabited are unexplored and the arts of production undeveloped, there is never anything more than a temporary and partial balancing of such actions. But when a society approaches the maturity of that type on which it is organised, the various industrial activities settle down into a comparatively constant state. Moreover, advance in organisation, as well as advance in growth, is conducive to a better equilibrium of industrial functions. While the diffusion of mercantile information is slow and the means of transport deficient, the adjustment of supply to demand is very imperfect. Great over-production of a commodity is followed by great under-production, and there results a rhythm having extremes that depart widely from the mean state in which demand and supply are equilibrated. But when good roads are made and there is a rapid diffusion of printed or written intelligence, and still more when railways and telegraphs come into existence—

when the periodical fairs of early days grow into weekly markets, and these into daily markets, there is gradually produced a better balance of production and consumption: the rapid oscillations of price within narrow limits on either side of a comparatively uniform mean indicate a near approach to equilibrium. Evidently this industrial progress has for its limit that which Mr. Mill has called "the stationary state." When population shall have become dense over all habitable parts of the globe; when the resources of every region have been fully explored; and when the productive arts admit of no further improvements; there must result an almost complete balance, both between the fertility and mortality in each society, and between its producing and consuming activities. Each society will exhibit only minor deviations from its average number, and the rhythm of its industrial functions will go on from day to day and year to year with comparatively insignificant perturbations.

One other kind of social equilibration has still to be considered:—that which results in the establishment of governmental institutions, and which becomes complete as these institutions fall into harmony with the desires of the people. Those aggressive impulses inherited from the pre-social state—those tendencies to seek self-satisfaction regardless of injury to other beings, which are essential to a predatory life, constitute an anti-social force tending ever to cause conflict and separation. Contrariwise, those desires which can be fulfilled only by co-operation and those which find satisfaction through intercourse with fellow-men, as well as those resulting in what we call loyalty, are forces tending to keep the units of a society together. On the one hand, there is in each man more or less of resistance against restraints imposed on his actions by other men—a resistance which, tending ever to widen each man's sphere of action, and reciprocally to limit the spheres of action of other men, constitutes a repulsive force mutually exercised by the members of a social aggregate. On the other hand, the general sympathy of man for man and the more special sympathy of each variety of man for others of the same variety, together with allied feelings which the social state gratifies, act as an attractive force, tending ever to keep united those who have a common ancestry. And since the resistances to be overcome in

satisfying the totality of their desires when living separately, are greater than the resistances to be overcome in satisfying the totality of their desires when living together, there is a residuary force that prevents separation. Like other opposing forces, those exerted by citizens on one another produce alternating movements which, at first extreme, undergo gradual diminution on the way to ultimate equilibrium. In small undeveloped societies, marked rhythms result from these conflicting tendencies. A tribe that has maintained its unity for a generation or two reaches a size at which it will no longer hold together; and, on the occurrence of some event causing unusual antagonism among its members, divides. Each primitive nation exhibits wide oscillations between an extreme in which the subjects are under rigid restraint, and an extreme in which the restraint fails to prevent rebellion and disintegration. In more advanced nations of like type, we always find violent actions and reactions of the same essential nature: "despotism tempered by assassination," characterizing a political state in which unbearable repression from time to time brings about a bursting of bonds. Among ourselves the conflicts between Conservatism (which stands for the restraints of society over the individual) and Reform (which stands for the liberty of the individual against society) fall within slowly approximating limits; so that the temporary predominance of either produces a less marked deviation from the medium state—a smaller disturbance of the moving equilibrium.

Of course in this case, as in preceding cases, there is involved a limit to the increase of heterogeneity. A few pages back, it was shown that an advance in mental evolution is the establishment of some further internal action corresponding to some further external action. We inferred that each such new function, involving some new modification of structure, implies an increase of heterogeneity; and that thus, increase of heterogeneity must go on while there remain any outer relations affecting the organism which are unbalanced by inner relations. Evidently the like must simultaneously take place with society. Each increment of heterogeneity in the individual implies, as cause or consequence, some increment of heterogeneity in the arrangements of the aggregate of individuals. And the limit to social complexity can be reached

only with the establishment of the equilibrium, just described, between social and individual forces.

§ 176. Here presents itself a final question, which has probably been taking shape in the minds of many while reading this chapter. "If Evolution of every kind is an increase in complexity of structure and function that is incidental to the universal process of equilibration, and if equilibration must end in complete rest, what is the fate towards which all things tend? If the Solar System is slowly dissipating its energies—if the Sun is losing his heat at a rate which will tell in millions of years—if with decrease of the Sun's radiations there must go on a decrease in the activity of geologic and meteorologic processes as well as in the quantity of vegetal and animal life—if Man and Society are similarly dependent on this supply of energy which is gradually coming to an end; are we not manifestly progressing towards omnipresent death?"

That such a state must be the outcome of the changes everywhere going on seems beyond doubt. Whether any ulterior process may reverse these processes and initiate a new life is a question to be considered hereafter. For the present it must suffice that the end of all the transformations we have traced is quiescence. This admits of *a priori* proof. The law of equilibration, not less than the preceding general laws, is deducible from the ultimate datum of consciousness.

The forces of attraction and repulsion being, as shown in § 74, universally co-existent, it follows that all motion is motion under resistance: either that exercised on the moving body by other bodies, or that exercised by the medium traversed. There are two corollaries. The first is that deductions perpetually made by the communication of motion to that which resists cannot but bring the motion of the body to an end in a longer or shorter time. The second is that the motion of the body cannot cease until these deductions destroy it. In other words, movement must continue while equilibration is incomplete, and equilibration must eventually become complete. Both these are manifest deductions from the persistence of force. Hence this primordial truth is our warrant for the conclusions that the changes which Evolution presents

cannot end until equilibrium is reached, and that equilibrium must at last be reached.

At the same time it follows that in every aggregate having compound motions, there results a comparatively early dissipation of the motions which are smaller and much resisted, followed by long continuance of the larger and less resisted motions; and that so there arise moving equilibria. Hence, also, may be inferred the tendency to conservation of such moving equilibria. For any new motion given to the parts of a moving equilibrium by a disturbing force, must either be such that it cannot be dissipated before the pre-existing motions, in which case it brings the moving equilibrium to an end; or else it must be such that it can be dissipated before the pre-existing motions, in which case the moving equilibrium is re-established.

Thus from the persistence of force follow, not only the various direct and indirect equilibrations going on around, together with that cosmical equilibration which brings Evolution under all its forms to a close, but also those less manifest equilibrations shown in the re-adjustments of moving equilibria that have been disturbed. By this ultimate principle is provable the tendency of every organism, disordered by some unusual influence, to return to a balanced state. To it also may be traced the capacity, possessed in a slight degree by individuals and in a greater degree by species, of becoming adapted to new circumstances. And not less does it afford a basis for the inference that there is a gradual advance towards harmony between man's mental nature and the conditions of his existence.

## CHAPTER XXIII

### DISSOLUTION

§ 177. When, in Chapter XII, we glanced at the cycle of changes through which every existence passes, in a short time or in a time almost infinitely long—when the opposite re-distributions of matter and motion implied were severally distinguished as Evolution and Dissolution, the natures of the two, and the conditions under which they respectively occur, were specified in general terms. Since then, we have contemplated the phenomena of Evolution in detail, and have followed them out to those states of equilibrium in which they all end. To complete the argument we must now contemplate, somewhat more in detail than before, the complementary phenomena of Dissolution. Not, indeed, that we need dwell long on Dissolution, which has none of those various and interesting aspects which Evolution presents; but something more must be said than has yet been said.

It was shown that neither of these two antagonist processes goes on unqualified by the other, and that a movement towards either is a differential result of the conflict between them. An evolving aggregate, while on the average losing motion and integrating, is always, in one way or other, receiving some motion and to that extent disintegrating; and after the integrative changes have ceased to predominate, the reception of motion, though perpetually checked by its dissipation, constantly tends to produce a reverse transformation, and eventually does produce it. When Evolution has run its course—when an aggregate has reached that equilibrium in which its changes end, it thereafter remains subject to all actions in its environment which may increase the quantity of motion it contains, and which in course of time are sure, either

slowly or suddenly, to give its parts such excess of motion as will cause disintegration. According as its size, its nature, and its conditions determine, its dissolution may come quickly or may be indefinitely delayed—may occur in a few days or may be postponed for billions of years. But exposed as it is to the contingencies not simply of its immediate neighbourhood but of a Universe everywhere in motion, the time must at last come when, either alone or in company with surrounding aggregates, it has its parts dispersed.

The process of dissolution so caused we have here to look at as it takes place in aggregates of different orders. The course of change being the reverse of that hitherto traced, we may properly take the illustrations of it in the reverse order—beginning with the most complex and ending with the most simple.

§ 178. Regarding the evolution of a society as at once an increase in the number of individuals integrated into a corporate body, an increase in the masses and varieties of the parts into which this corporate body divides, as well as of the actions called their functions, and an increase in the degree of combination among these massess and their functions; we shall see that social dissolution conforms to the general law in being, materially considered, a disintegration, and, dynamically considered, a decrease in the movements of wholes and an increase in the movements of parts; while it further conforms to the general law in being caused by an excess of motion in some way or other received from without.

It is obvious that the social dissolution which follows the aggression of another nation, and which, as history shows us, is apt to occur when social evolution has ended and decay has begun, is, under its broadest aspect, the reception of a new external motion; and when, as sometimes happens, the conquered society is dispersed, or when its component divisions fall apart, its dissolution is literally a cessation of those corporate movements which the society, both in its army and in its industrial bodies, presented, and a lapse into individual or uncombined movements.

Again, social disorder, however caused, entails a decrease of integrated movements and an increase of disintegrated movements. As the disorder progresses the political actions previously combined become uncombined: there arise the antagonistic actions of

riot or revolt. Simultaneously, the industrial and commercial processes that were co-ordinated throughout the body politic are broken up; and only the local, or small, trading transactions continue. And each further disorganizing change diminishes the joint operations by which men satisfy their wants, and leaves them to satisfy their wants, as best they can, by separate operations. Of the way in which such disintegrations are set up in a society that has evolved to the limit of its type, and reached a state of moving equilibrium, a good illustration is furnished by Japan. The finished fabric into which its people had organized themselves, maintained an almost constant state so long as it was preserved from fresh external forces. But as soon as it received an impact from European civilization, partly by armed aggression, partly by commercial impulse, partly by the influence of ideas, this fabric began to fall to pieces. There is now in progress a political dissolution.* Probably a political reorganization will follow; but, be this as it may, the change thus far produced by an outer action is a change towards dissolution—a change from integrated motions to disintegrated motions.

Even where a society, that has developed into the highest form permitted by the characters of its units, begins to dwindle and decay, the progressive dissolution is still essentially of the same nature. Decline of numbers is, in such case, brought about partly by emigration; for a society having the fixed structure in which evolution ends is one that will not yield and modify under pressure of population: so long as its structure is plastic it is still evolving. Hence the surplus population is continually dispersed: the influences brought to bear on the citizens by other societies cause their detachment, and there is an increase of the uncombined motions of units instead of an increase of combined motions. Gradually as the society becomes still less capable of changing into the form required for successful competition with more plastic societies, the number of citizens who can live within its unyielding framework becomes positively smaller. Hence it dwindles both through continued emigration and through the diminished multiplication that follows innutrition. And this further dwindling is similarly a decrease in the total quantity of combined

* This was written in 1867.

motion and an increase in the quantity of uncombined motion—as we shall presently see when we come to deal with individual dissolution.

Considering, then, that social aggregates differ so much from aggregates of other kinds, formed, as they are, of units held together loosely and indirectly, in such variable ways by such complex forces, the process of dissolution among them conforms to the general law quite as clearly as could be expected.

§ 179. When from these super-organic aggregates we descend to organic aggregates, the truth that Dissolution is a disintegration of matter caused by the reception of additional motion from without becomes easily demonstrable. We will look first at the transformation and afterwards at its cause.

Death, or that final equilibration which precedes dissolution, is the bringing to a close all those many conspicuous integrated motions that arose during evolution. The impulsions of the body from place to place first cease; presently the limbs cannot be stirred; later still the respiratory actions stop; finally the heart becomes stationary and, with it, the circulating fluids. That is, the transformation of molecular motion into the motion of masses comes to an end. The process of decay involves an increase of insensible movements; since these are far greater in the gases generated than they are in the fluid-solid matters out of which the gases arise. Each of the complex chemical units composing an organic body possesses a rhythmic motion in which its many component units jointly partake. When decomposition breaks up these complex molecules, and their constituents assume gaseous forms, there is, besides that increase of motion implied by diffusion, a resolution of such motions as the complex molecules possessed into motions of their constituent molecules. So that in organic dissolution we have, first, an end put to that transformation of the motions of units into the motions of aggregates, which constitutes evolution dynamically considered; and we have afterwards, though in a subtler sense, a transformation of the motions of aggregates into the motions of units. Still it is not thus shown that organic dissolution answers to the general definition of dissolution— the absorption of motion and con-

comitant disintegration of matter. The disintegration of matter is, indeed, conspicuous enough; but the absorption of motion is not conspicuous. True, the fact that motion has been absorbed may be inferred from the fact that particles previously integrated into a solid mass, occupying a small space, have most of them moved away from one another and now occupy a great space; for the motion implied by this expansion must have been obtained from somewhere. But its source is not obvious. A little search, however, will bring us to its derivation.

At a temperature below the freezing point of water, decomposition of organic matter does not take place. Dead bodies kept at this temperature are prevented from decomposing for an indefinitely long period: witness the frozen carcases of mammoths (elephants of a species long ago extinct) that are found imbedded in the ice at the mouths of Siberian rivers; and which, though they have been there for many thousands of years, have flesh so fresh that when at length exposed it is devoured by wolves. What, now, is the meaning of such exceptional preservations? A body kept below freezing point, is a body which receives very little heat by radiation or conduction; and the reception of but little heat is the reception of but little molecular motion. That is to say, in an environment which does not furnish it with molecular motion passing a certain amount, an organic body does not undergo dissolution. Confirmatory evidence is yielded by the variations in rate of dissolution which accompany variations of temperature. All know that in cool weather the organic substances used in our households keep longer, as we say, than in hot weather. Equally certain, if less familiar, is the fact that in tropical climates decay proceeds much more rapidly than in temperate climates. Thus, dispersion of the dead body into gases is rapid in proportion as the molecular motion received from without is great. The still quicker decompositions produced by exposure to artificially-raised temperatures afford further proofs: instance those which occur in cooking. The charred surfaces of parts much heated, show us that the molecular motion absorbed has served to dissipate in gaseous forms all the elements but the carbon.

The nature and causes of Dissolution are thus clearly displayed by the aggregates which so clearly display the nature and causes

of Evolution. One of these aggregates, being made of that peculiar matter to which a large quantity of constitutional motion gives great plasticity and the ability to evolve into a highly complex form (§ 103); it results that after evolution has ceased, a small amount of molecular motion added to that already contained in its peculiar matter suffices to cause dissolution. Though at death there is reached an equilibrium among the sensible masses, or organs, which make up the body; yet, as the insensible units or molecules of which these organs consist are chemically unstable, small incident forces suffice to overthrow them, and hence disintegration proceeds rapidly.

§ 180. Most inorganic aggregates, having arrived at dense forms in which comparatively little motion is retained, remain long without marked changes. Each has lost so much motion in passing from the unintegrated to the integrated state, that much motion must be given to it to cause resumption of the unintegrated state; and an immense time may elapse before there occur in the environment changes great enough to communicate to it the requisite quantity of motion. We will look first at those few inorganic aggregates which retain much motion, and therefore readily undergo dissolution.

Among these are the liquids and volatile solids which dissipate under ordinary conditions—water that evaporates, camphor that wastes away by the dispersion of its molecules. In all such cases motion is absorbed; and always the dissolution is rapid in proportion as the quantity of heat or motion which the mass receives from its environment is great. Next come the cases in which the molecules of a highly integrated or solid aggregate are dispersed among the molecules of a less integrated or liquid aggregate; as in aqueous solutions. One evidence that this disintegration of matter has for its concomitant the absorption of motion is that soluble substances dissolve the more quickly the hotter the water: supposing always that no elective affinity comes into play. Another and still more conclusive evidence is that, when crystals of a given temperature are placed in water of the same temperature, the process of solution is accompanied by a fall of temperature —often a very great one. Omitting instances in which some

chemical action takes place between the salt and the water, it is a uniform law that the motion which disperses the molecules of the salt through the water is at the expense of the molecular motion possessed by the water. An allied and still better example is furnished by cases in which the dissolution of two solids results from mixing them, as happens with snow and salt. Here dissolution necessitates so great an absorption of molecular motion as greatly to lower the temperature of the liquid produced.

Masses of sediment accumulated into strata, afterwards compressed by many thousands of feet of superincumbent strata, and reduced in course of time to a solid state, may remain for untold millions of years unchanged; but in subsequent millions of years they are inevitably exposed to disintegrating actions. Raised along with other such masses into a continent, denuded and exposed to rain, frost, and the grinding actions of glaciers, they have their particles gradually separated, carried away, and widely dispersed. Or when, as otherwise happens, the encroaching sea arrives, the undermined cliffs formed of them fall from time to time; the waves, rolling about the small pieces, and in storms knocking together the larger blocks, reduce them to boulders and pebbles, and at last to sand and mud. Even if portions of the disintegrated strata accumulate into shingle banks which afterwards become solidified, the process of dissolution, arrested though it may be for some enormous geologic period, is finally resumed. As many a shore shows us, the conglomerate itself is sooner or later subject to the like processes; and its cemented masses of heterogeneous components are broken up and worn away by impact and attrition—that is, by communicated mechanical motion.

When not thus effected, the disintegration is effected by communicated molecular motion. A consolidated stratum in some area of subsidence, brought down nearer and nearer to the regions occupied by molten matter, comes eventually to have its particles brought to a plastic state by heat, or finally melted down into liquid. Whatever may be its subsequent transformations, the transformation then exhibited by it is an absorption of motion and disintegration of matter.

Thus be it simple or compound, small or large, a crystal or a mountain chain, every inorganic aggregate on the Earth undergoes,

at some time or other, a reversal of those changes undergone during its evolution. Not that it usually passes back from the perceptible into the imperceptible, during any period in which it is or can be exposed to human observation. It does not become aëriform and invisible, as organic aggregates do in great part, though not wholly. But still its disintegration and dispersion carry it some distance on the way towards the imperceptible; and there are reasons for thinking that its arrival there is but delayed. At a period immeasurably remote, every such inorganic aggregate, along with all undissipated remnants of organic aggregates, must be reduced to a state of gaseous diffusion, and so complete the cycle of its changes.

§ 181. For the Earth as a whole, when it has gone through the entire series of its ascending transformations, must remain exposed to the contingencies of its environment; and in the course of those ceaseless changes going on throughout a Universe of which all parts are in motion, must, at some period beyond the utmost stretch of imagination, be subject to energies sufficient to cause its complete disintegration. Let us glance at the energies competent to disintegrate it.

In his essay on "The Inter-action of Natural Forces," Prof. Helmholtz states the thermal equivalent of the Earth's movement through space, as calculated on the now received datum of Mr. Joule. "If our Earth," he says, "were by a sudden shock brought to rest in her orbit—which is not to be feared in the existing arrangement of our system—by such a shock a quantity of heat would be generated equal to that produced by the combustion of fourteen such Earths of solid coal. Making the most unfavourable assumption as to its capacity for heat, that is, placing it equal to that of water, the mass of the Earth would thereby be heated 112,000 degrees [Centigrade]; it would therefore be quite fused, and for the most part reduced to vapour. If then the Earth, after having been thus brought to rest, should fall into the Sun, which of course would be the case, the quantity of heat developed by the shock would be 400 times greater." Now though this calculation seems to be nothing to the purpose, since the Earth is not likely to be suddenly arrested in its orbit and not likely therefore suddenly to fall into

the Sun; yet, as before pointed out (§ 171), there is a force at work which it is held must at last bring the Earth into the Sun. This force is the resistance of the ethereal medium. From ethereal resistance is inferred a retardation of all moving bodies in the Solar System—a retardation which some astronomers contend even now shows its effects in the relative nearness to one another of the orbits of the older planets. If, then, retardation is going on, there must come a time, no matter how remote, when the slowly diminishing orbit of the Earth will end in the Sun; and, though the quantity of molar motion to be then transformed into molecular motion will not be so great as that which the calculation of Helmholtz supposes, it will be great enough to reduce the substance of the Earth to a gaseous state.

This dissolution of the Earth and, at intervals, of every other planet, is not, however, a dissolution of the Solar System. All the changes exhibited throughout the Solar System are incidents accompanying the integration of the entire matter composing it: the local integration of which each planet is the scene completing itself long before the general integration is complete. But each secondary mass having gone through its evolution and reached a state of equilibrium among its parts (supposing that the available time suffices, which in the cases of Jupiter and Saturn it may not), thereafter continues in its extinct state, until, by the still-progressing general integration, it is brought into the central mass. And though each such union of a secondary mass with the central mass, implying transformation of molar motion into molecular motion, causes partial diffusion of the total mass formed, and adds to the quantity of motion that has to be dispersed in the shape of light and heat; yet it does but postpone the period at which the total mass must become completely integrated, and its excess of contained motion radiated into space.

§ 182. Here we come to the question raised at the close of the last chapter—Does Evolution as a whole, like Evolution in detail, advance towards complete quiescence? Is that motionless state called death, which ends Evolution in organic bodies, typical of the universal death in which Evolution at large must end? And have we thus to contemplate as the outcome of things, a boundless

space holding here and there extinct suns, fated to remain for ever without further change.

To so speculative an inquiry none but a speculative answer is to be expected. Such answer as may be ventured must be taken less as a positive answer than as a demurrer to the conclusion that the proximate result must be the ultimate result. If, pushing to its extreme the argument that Evolution must come to a close in complete equilibrium or rest, the reader suggests that for aught which appears to the contrary there must result a Universal Death which will continue indefinitely, two replies may be made. The first is that the evidence presented in the heavens at large implies that while of the multitudinous aggregates of matter it presents, most are passing through those stages which must end in local rest, there are others which, having barely commenced the series of changes constituting Evolution, are on the way to become theatres of life. The second reply is that when we contemplate our Sidereal System as a whole, certain of the great facts which science has established imply potential renewals of life, now in one region now in another; followed, possibly, at a period unimaginably remote by a more general renewal. This conclusion is suggested when we take into account a factor not yet mentioned.

For hitherto we have considered only that equilibration which is taking place within our Solar System and within similar systems: taking no note of that immeasurably greater equilibration which remains to take place: ending those motions through space which such systems possess. That the stars, in old times called fixed, are all in motion, has now become a familiar truth, and that they are moving with velocities ranging from say 10 miles per second up to some 70 miles per second (which last is the velocity of a "runaway star" supposed to be passing through our Sidereal System) is a truth deduced from observations by modern astronomers. To be joined with this is the fact that there are dying stars and probably dead stars. Beyond the evidence furnished by the various kinds of light they emit, of which the red indicates relatively advanced age, there is the evidence that in some cases bright stars have attendants which are dark or almost dark: the most conspicuous case being that of Sirius, round which revolves a body of about one-third its size but yielding only 1/39,000th

part of its light—a star, approaching to our Sun in size, which has gone out. The implication appears to be that beyond the luminous masses constituting the visible Sidereal System, there are non-luminous masses, perhaps fewer in number perhaps more numerous, which in common with the luminous ones are impelled by mutual gravitation. How then are to be equilibrated the motions of these vast masses, luminous and non-luminous, having high velocities?

This question may be divided into two, a major and a minor, of which the minor admits of something like an answer, while the major seems unanswerable.

§ 182*a*. Scattered through immensurable space, but more especially in and about the region of the Milky Way, are numerous star-clusters, varying in their characters from those which are hardly distinguishable from unusually rich proportions of the heavens, to those which constitute condensed swarms of stars: kinds of which may be named, as at the one extreme, 34 Persei, 103 Cassiopeia, and 32 Cygni, and at the other extreme, 13 Herculis and 2 Aquarii.* The varieties between these extremes were regarded by Sir William Herschel as implying progressive concentration; and in his opinion Sir John Herschel apparently agreed. Pursuing the argument the latter wrote:—

"Among a crowd of solid bodies of whatever size, animated by independent and partially opposing impulses, motions opposite to each other *must* produce collision, destruction of velocity, and subsidence or near approach towards the centre of preponderant attraction; while those which conspire, or which remain outstanding after such conflicts, *must* ultimately give rise to circulation of a permanent character." (*Outlines of Astronomy*, 9th ed., p. 641.)

The problem, however, is here dealt with purely as a mechanical one: the assumption being that the mutually arrested masses will continue as masses. Writing in 1849 Sir John Herschel did not take account of the results, reached and verified during the few

* The clusters here named are exhibited in Dr. Isaac Roberts's splendid series of *Photographs of Stars, Star-Clusters, and Nebulæ* (two vols.), in which also will be found the references presently to be made.

preceding years by Mayer and Joule, respecting the quantitative equivalence between motion and heat. But accepting, as we must now do, the conclusion drawn by Helmholtz (§ 171) congruous with one previously drawn by Mayer, we are obliged to infer that stars moving at the high velocities acquired during concentration, will, by mutual arrest, be dissipated into gases of extreme tenuity, constituting what we conceive as nebulous matter. When we infer this the problem becomes different; and a different conclusion seems unavoidable. For the diffused matter produced by such conflicts must form a resisting medium, occupying that central region of the cluster through which its members from time to time pass in describing their orbits—a resisting medium which they cannot move through without having their velocities diminished. Every additional collision, by augmenting this resisting medium, and making the losses of velocity greater, must aid in preventing the establishment of that equilibrium which would else arise; and so must conspire to produce more frequent collisions. And the nebulous matter thus formed, presently enveloping the whole cluster, must, by continuing to shorten the gyrations of the moving masses, entail an increasingly active integration and reactive disintegration of them, until they are all dissipated.*

Products of the kind implied are presented in the large, diffused, and irregular nebulæ, such as the one in Orion. Sir John Herschel describes them (p. 650) as "of very great extent," "irregular and capricious in their shapes," "no less so in the distribution of their light," and not having "any similarity of figure or aspect." And then he remarks that "they have one important character in common"—"they are all situated in, or very near, the borders of the Milky Way." That is to say, they are found in that region of

* I leave these three sentences as they stood in the revised edition of this work published in 1867, because evidence since obtained goes far to show that the process described is going on. In the photographs contained in the second volume of his *Stars, Star-Clusters, and Nebulæ*, and by the accompanying description, Dr. Roberts shows that in some of them (as instance, M. 3 Canum Venaticorum) there is distinctly visible a nebulous central region, such as might be produced at early stages of the process described; and that he conceives such a process to be taking place is proved by his remarks on page 178.

the heavens in which star-clusters also are most abundant. Thus in their distribution and in their characters these nebulæ are congruous with the supposition that they have resulted from dissipation of clusters arising in the way described.

What may we say concerning the future of one of these vast irregular nebulæ? The first remark is that as, in conformity with the foregoing speculation, it contains the matter not of one star but of many stars, so in conformity with its aspect it is not a nebulous mass of the kind out of which a single star or sun originates: being so large that it covers numerous interstellar spaces. The second remark is that when its widest diffusion has been reached concentration will commence, and the implication is that after an immense period a rotating nebula of one or other of the kinds so abundantly exemplified will result. That a spiral nebula is produced by concentration of one of these vast diffused masses, containing the matter of many stars, is an inference supported by the fact that in some spiral nebulæ many stars and nebulous stars embedded within the spiral structure have manifestly been formed or are forming while the general concentration is going on—instance 74 Piscium, 100 Comæ and M. 51 Canum Venaticorum—and suggesting that a new concentrating cluster will eventually arise. If so, the implication appears to be that there will eventually again arise a process like that just suggested—collisions of concentrating masses and progressing diffusion until the nebulous form is again produced.

If in pursuance of this view we regard (1) the star-clusters variously condensed, (2) the diffused and irregular nebulæ, (3) the spiral and other nebulæ that are concentrating into star-systems, as exhibiting different stages of the same process, then the implication is that in many thousands of places throughout our Sidereal System there are going on alternations of Evolution and Dissolution. And this conception may be taken as a sufficient answer to the inference above drawn that equilibration must end in universal death—a speculative demurrer to a speculative conclusion.

§ 182*b*. There still presents itself the question which, unanswerable though it may be, we cannot ignore—What are we to think concerning the future of the visible Universe? To the conception of

alternating evolutions and dissolutions taking place in multitudinous different parts of it, there must be joined the conception of it as either remaining in its present state or as changing; and that raises the question—Changing towards what other state? That its state must change is clear: the irregular distribution of it being such as to render even a temporary moving equilibrium impossible.

At the outset there arises the doubt whether our Sidereal System is an aggregate at all, in such sense as is implied by conformity to the law of Evolution and Dissolution—whether it does not transcend those limits implied by conformity to the law. When, reducing its stars and their distances to dimensions that may be imagined, we think of them as comparable to peas one hundred miles apart, the conception of them as forming a whole held together only by mutual gravitation seems somewhat strained. The assumed unity seems more questionable on observing the marks of independence in the dispersed parts. Besides multitudinous cases of the kind above described in which star-clusters apparently carry on their transformations irrespective of the Sidereal System as a whole, there are some far larger local transformations that appear to be of kindred nature. I refer to those going on in the Magellanic clouds or nubeculæ, major and minor —two closely-packed agglomerations, not, indeed, of single stars only, but of single stars, of clusters regular and irregular, of nebulæ, and of diffused nebulosity. That these have been formed by mutual gravitation of parts once widely scattered, there is evidence in the barrenness of the surrounding celestial spaces: the nubecula minor especially, being seated, as Humboldt says, in "a kind of starless desert." And since the traits of these chaotic aggregates are such as do not consist with any process of evolution, we must infer that they are passing through the counter-process of dissolution: the resulting nebulous matter having already enveloped large portions of their miscellaneous components: a conclusion receiving support from the fact that while the one lies in a space devoid of stars the other has around it numerous outlying nebulæ and star-clusters, which must in course of time be drawn into it. Thus there are considerable difficulties in the way of regarding our Sidereal System as a whole subject to the processes of evolution and dissolution.

Nevertheless sundry traits seem to imply that throughout a past so immense that the time occupied in the evolution of a solar or stellar system becomes by comparison utterly insignificant, there has been a gathering together of the matter of our Universe from a more dispersed state; and its disc-like form, or else annular form, indicated by the encircling appearance of the Milky Way, raises the thought that it has a combined motion within which all minor motions are included. Moreover the contrast between the galactic circle, with its closely packed millions of stars dotted with numerous star-clusters, and the regions about the galactic poles, in which the more regular nebulæ are chiefly congregated, yields further evidence that our Sidereal System has some kind of unity, and that during an immeasurable past it has undergone transformations due to general forces. If, then, we must contemplate the visible Universe as an aggregate, subject to processes of evolution and dissolution of the same essential nature as those traceable in minor aggregates, we cannot avoid asking what is likely to be its future.

In his *Outlines of Astronomy* (pp. 630–1), Sir John Herschel refers to speculation respecting the rotation of our Sidereal System in the plane of the galactic circle. Dismissing the hypothesis of Mädler that the centre of rotation is in the Pleiades, he thinks that no opinion can reasonably be formed whether rotation exists or not, until after some thirty or forty years of observations of a special class. In any case, however, the irregularities of the Milky Way necessitate the conclusion that there is going on, and must continue to go on, a general change of structure. The greater massiveness of it in the northern than in the southern hemisphere, the cleft form, the breach of continuity, the branchings, the narrow connecting necks, and the parts that are almost or quite islanded, exclude the idea of equilibrium, whether the system as a whole be stationary or whether it be rotating. In § 150, when referring to the fate of nebulous rings, I cited the opinion of Sir John Herschel to the effect that a nebulous ring would not break at one place and collapse, but would break at many places and form separate masses. I joined with it the opinion of Sir G. B. Airy, to whom I put the question whether these would remain separate, and who agreed that the

masses thus formed, parting more widely at some one place, would eventually collapse into a single mass. Parallel conclusions respecting changes in the Milky Way seem legitimate, or rather, indeed, seem necessitated. Separation of it into parts—minor Sidereal Systems—is a result to which its present aspect points. That such minor sidereal systems could remain permanently independent is not to be supposed. Mutual attraction would cause in some cases the formation of binary sidereal systems, and in other cases coalescence, according to the directions and amounts of their respective proper motions. The implication is that there may be repeated, on vaster scales, changes like those described as occurring in star-clusters: local concentrations taking place within these minor sidereal systems, with resulting evolutions and dissolutions, at the same time that the minor sidereal systems themselves, progressively uniting, become more condensed, and consequently the scenes of more active changes of like kinds. If, giving imagination the rein, we suppose this process carried to its limit, and ultimately to present on an immensely larger scale the kind of change which the nubeculæ exhibit, there arises the thought of a progressing destruction of the molar motions possessed by the concentrating stars, and a simultaneous diffusion of their substances, which, as the process comes to a close, spreads the matter of the Sidereal System in its nebulous form throughout the whole of that space which it originally filled—a diffusion reversing the preceding concentration—a dissolution that prepares the way for a new evolution. Reduced to its abstract form, the argument is that the quantity of motion implied by dispersion must be as great as the quantity of motion implied by aggregation, or rather must be the same motion, taking now the molar form and now the molecular form; and if we allow ourselves to conceive this as an ultimate result there arises the conception not only of local evolutions and dissolutions throughout our Sidereal System but of general evolutions and dissolutions alternating indefinitely.

But we cannot draw such a conclusion without tacitly assuming something beyond the limits of possible knowledge, namely, that the energy contained in our Sidereal System remains undiminished. Continuance of such alternations without end presupposes that the quantity of molecular motion radiated by each star in the course

of its formation from diffused matter, shall either not escape from our Sidereal System or shall be compensated by an equal quantity of molecular motion radiated into it from other parts of space. If the ether which fills the interspaces of our Sidereal System has a boundary somewhere beyond the outermost stars, it is inferable that motion is not lost by radiation beyond that boundary; and if so the original degree of diffusion may be resumed. Or if, supposing that the ether is unbounded, the temperature of space is the same within and without our Sidereal System, then it is inferable that the quantity of motion contained within our Sidereal System remaining undiminished, its alternate concentrations and diffusions may continue undiminished. But we shall never be able to say whether either condition is fulfilled.

We may indeed dismiss such questions as passing the bounds of rational speculation. They have here been touched upon for the purpose of showing that it is not inferable from the general progress towards equilibrium that a state of universal quiescence or death will be reached; but that if a process of reasoning ends in that conclusion, a further process of reasoning points to renewals of activity and life.

Here, however, it is needless for the adequate presentation of the general doctrine that Evolution and Dissolution should be traced in either direction to their ends. In § 93 it was said that no actual philosophy can fill out the scheme of an ideal philosophy—cannot even of a small aggregate trace the entire history from its appearance to its disappearance, and must be immeasurably far from doing this with the all-comprehensive aggregate.

But unable though we must ever remain to give a complete account of the transformation of things, even in any of its minor parts, and still more in its totality, we are able to recognize throughout it the same general law; and may reasonably infer that it holds in those parts of the transformation which are beyond the reach of our intelligence as it does in those parts which are within its reach.

## CHAPTER XXIV

### SUMMARY AND CONCLUSION

§ 184. At the close of a work like this, it is more than usually needful to contemplate as a whole that which the successive chapters have presented in parts. A coherent knowledge implies something more than the establishment of connexions: we must not rest after seeing how each minor group of truths falls into its place within some major group, and how all the major groups fit together. It is requisite that we should retire a space, and, looking at the entire structure from a distance at which details are lost to view, observe its general character.

Something more than recapitulation—something more even than an organized re-statement, will come within the scope of the chapter. We shall find that in their *ensemble* the general truths reached exhibit, under certain aspects, a oneness not hitherto observed.

There is, too, a special reason for noting how the various divisions and subdivisions of the argument consolidate; namely, that the theory at large thereby obtains a final illustration. The reduction of the generalizations which have been set forth separately to a completely integrated state exemplifies once more the process of Evolution, and strengthens still further the general fabric of conclusions.

§ 185. Here, indeed, we find ourselves brought round unexpectedly to the truth with which we set out, and with which our re-survey must commence. For this integrated form of knowledge is the form which, apart from the doctrine of Evolution, we decided to be the highest form.

When we inquired what constitutes Philosophy—when we compared men's various conceptions of Philosophy, so that, eliminating the elements in which they differed, we might see in what they agreed ; we found in them all the tacit implication that Philosophy is completely unified knowledge. Apart from each scheme of unified knowledge, and apart from proposed methods by which unification is to be effected, we traced in every case a belief that unification is possible, and that the end of Philosophy is achievement of it.

After reaching this conclusion we considered the data with which Philosophy must set out. Fundamental propositions, or propositions not deducible from deeper ones, can be established only by showing the complete congruity of all the results reached through the assumption of them ; and, premising that they were simply assumed till thus established, we took as our data those components of our intelligence without which there cannot go on the mental processes implied by philosophizing.

From the specification of these we passed to certain primary truths—"The Indestructibility of Matter," "The Continuity of Motion," and "The Persistence of Force"; of which the last is ultimate and the others derivative. Having previously seen that our experiences of Matter and Motion are resolvable into experiences of Force, we further saw the truths that Matter and Motion are unchangeable in quantity to be implications of the truth that Force is unchangeable in quantity. This we concluded is the truth by derivation from which all other truths are to be proved.

The first of the truths which presented itself to be so proved, is "The Persistence of the Relations among Forces." This, which is ordinarily called Uniformity of Law, we found to be a necessary implication of the truth that Force can neither arise out of nothing nor lapse into nothing.

The next deduction was that forces which seem to be lost are transformed into their equivalents of other forces; or, conversely, that forces which become manifest do so by disappearance of preexisting equivalent forces. These truths we found illustrated by the motions of the heavenly bodies, by the changes going on over the Earth's surface, and by all organic and super-organic actions.

It was shown to be the same with the law that everything moves along the line of least resistance, or the line of greatest traction, or their resultant. Among movements of all orders, from those of stars down to those of nervous discharges and commercial currents, it was shown both that this is so, and that, given the Persistence of Force, it must be so.

So, too, we saw it to be with "The Rhythm of Motion." All motion alternates—be it the motion of planets in their orbits or ethereal molecules in their undulations—be it the cadences of speech or the rises and falls of prices; and, as before, it became manifest that Force being persistent, this perpetual reversal of Motion between limits is inevitable.

§ 186. These truths holding of existences at large, were recognized as of the kind required to constitute what we distinguish as Philosophy. But, on considering them, we perceived that as they stand they do not form a Philosophy; and that a Philosophy cannot be formed by any number of such truths separately known. Each expresses the law of some one factor by which phenomena, as we experience them, are produced; or, at most, expresses the law of co-operation of some two factors. But knowing what are the elements of a process is not knowing how these elements combine to effect it. That which alone can unify knowledge must be the law of co-operation of the factors—a law expressing simultaneously the complex antecedents and the complex consequents which any phenomenon as a whole presents.

A further inference was that Philosophy, as we understand it, must not unify the changes displayed in separate concrete phenomena only; and must not stop short with unifying the changes displayed in separate classes of concrete phenomena; but must unify the changes displayed in all concrete phenomena. If the law of operation of each factor holds true throughout the Cosmos, so, too, must the law of their co-operation. And hence in comprehending the Cosmos as conforming to this law of co-operation, must consist that highest unification which Philosophy seeks.

Descending to a more concrete view, we saw that the law sought must be the law of the continuous re-distribution of Matter and Motion. The changes everywhere going on, from those which

are slowly altering the structure of our galaxy down to those which constitute a chemical decomposition, are changes in the relative positions of component parts; and everywhere necessarily imply that along with a new arrangement of Matter there has arisen a new arrangement of Motion. Hence it follows that there must be a law of the concomitant re-distribution of Matter and Motion which holds of every change, and which, by thus unifying all changes, must be the basis of a Philosophy.

In commencing our search for this universal law of re-distribution, we contemplated from another point of view the problem of Philosophy, and saw that its solution could not but be of the nature indicated. It was shown that an ideally complete Philosophy must formulate the whole series of changes passed through by existences separately and as a whole in passing from the imperceptible to the perceptible and again from the perceptible to the imperceptible. If it begins its explanations with existences that already have concrete forms, or leaves off while they still retain concrete forms, then, manifestly, they had preceding histories, or will have succeeding histories, or both, of which no account is given. Whence we saw it to follow that the formula sought, equally applicable to existences taken singly and in their totality, must be applicable to the whole history of each and to the whole history of all. This must be the ideal form of a Philosophy, however far short of it the reality may fall.

By these considerations we were brought within view of the formula. For if it had to express the entire progress from the imperceptible to the perceptible and from the perceptible to the imperceptible; and if it was also to express the continuous re-distribution of Matter and Motion, then, obviously, it could be no other than one defining the opposite processes of concentration and diffusion in terms of Matter and Motion. And if so, it must be a statement of the truth that the concentration of Matter implies the dissipation of Motion, and that, conversely, the absorption of Motion implies the diffusion of Matter.

Such, in fact, we found to be the law of the entire cycle of changes passed through by every existence. Moreover we saw that besides applying to the whole history of each existence, it applies to each detail of the history. Both processes are going on

at every instant; but always there is a differential result in favour of the first or the second. And every change, even though it be only a transposition of parts, inevitably advances the one process or the other.

Evolution and Dissolution, as we name these opposite transformations, though thus truly defined in their most general characters, are but incompletely defined; or rather, while the definition of Dissolution is sufficient, the definition of Evolution is extremely insufficient. Evolution is always an integration of Matter and dissipation of Motion; but it is in nearly all cases much more than this. The primary re-distribution of Matter and Motion is accompanied by secondary re-distributions.

Distinguishing the different kinds of Evolution thus produced as simple and compound, we went on to consider under what conditions the secondary re-distributions which make Evolution compound, take place. We found that a concentrating aggregate which loses its contained motion rapidly, or integrates quickly, exhibits only simple Evolution; but in proportion as its largeness, or the peculiar constitution of its components, hinders the dissipation of its motion, its parts, while undergoing that primary re-distribution which results in integration, undergo secondary re-distributions producing more or less complexity.

§ 187. From this conception of Evolution and Dissolution as together making up the entire process through which things pass; and from this conception of Evolution as divided into simple and compound; we went on to consider the law of Evolution, as exhibited among all orders of existences, in general and in detail.

The integration of Matter and concomitant dissipation of Motion, was traced not in each whole only, but in the parts into which each whole divides. By the aggregate Solar System, as well as by each planet and satellite, progressive concentration has been, and is still being, exemplified. In each organism that general incorporation of dispersed materials which causes growth is accompanied by local incorporations, forming what we call organs. Every society, while it displays the aggregative process by its increasing mass of population, displays it also by the rise of dense masses in special parts of its area. And in all cases,

along with these direct integrations there go the indirect integrations by which parts are made mutually dependent.

From this primary re-distribution we were led on to consider the secondary re-distributions, by inquiring how there came to be a formation of parts during the formation of a whole. It turned out that there is habitually a passage from homogeneity to heterogeneity, along with the passage from diffusion to concentration. While the matter composing the Solar System has been assuming a denser form, it has changed from unity to variety of distribution. Solidification of the Earth has been accompanied by a progress from comparative uniformity to extreme multiformity. In the course of its advance from a germ to a mass of relatively great bulk, every plant and animal also advances from simplicity to complexity. The increase of a society in numbers and consolidation has for its concomitant an increased heterogeneity both of its political and its industrial organization. And the like holds of all super-organic products—Language, Science, Art, and Literature.

But we saw that these secondary re-distributions are not thus completely expressed. While the parts into which each whole is resolved become more unlike one another, they also become more sharply marked off. The result of the secondary re-distributions is therefore to change an indefinite homogeneity into a definite heterogeneity. This additional trait also we found in evolving aggregates of all orders. Further consideration, however, made it apparent that the increasing definiteness which goes along with increasing heterogeneity is not an independent trait, but that it results from the integration which progresses in each of the differentiating parts while it progresses in the whole they form.

Further, it was pointed out that in all evolutions, inorganic, organic, and super-organic, this change in the arrangement of Matter is accompanied by a parallel change in the arrangement of contained Motion: every increase in structural complexity involving a corresponding increase in functional complexity. It was shown that along with the integration of molecules into masses, there arises an integration of molecular motion into the motion of masses; and that as fast as there results variety in the

sizes and forms of aggregates and their relations to incident forces, there also results variety in their movements.

The transformation thus contemplated under separate aspects, being in itself but one transformation, it became needful to unite these separate aspects into a single conception—to regard the primary and secondary re-distributions as simultaneously working their various effects. Everywhere the change from a confused simplicity to a distinct complexity, in the distribution of both matter and motion, is incidental to the consolidation of the matter and the loss of its internal motion. Hence the re-distribution of the matter and of its retained motion is from a relatively diffused, uniform, and indeterminate arrangement, to a relatively concentrated, multiform, and determinate arrangement.

§ 188. We come now to one of the additions that may be made to the general argument while summing it up. Here is the fit occasion for observing a higher degree of unity in the foregoing inductions than we observed while making them.

The law of Evolution has been thus far contemplated as holding true of each order of existences, considered as a separate order. But the induction as so presented falls short of that completeness which it gains when we contemplate these several orders of existences as forming together one natural whole. While we think of Evolution as divided into astronomic, geologic, biologic, psychologic, sociologic, &c., it may seem to some extent a coincidence that the same law of metamorphosis holds throughout all its divisions. But when we recognize these divisions as mere conventional groupings, made to facilitate the arrangement and acquisition of knowledge—when we remember that the different existences with which they severally deal are component parts of one Cosmos; we see at once that there are not several kinds of Evolution having certain traits in common, but one Evolution going on everywhere after the same manner. We have repeatedly observed that while any whole is evolving, there is always going on an evolution of the parts into which it divides itself; but we have not observed that this equally holds of the totality of things, which is made up of parts within parts from the greatest down to the smallest. We know that while a physically-cohering aggregate like the human

body is getting larger and taking on its general shape, each of its organs is doing the same; that while each organ is growing and becoming unlike others, there is going on a differentiation and integration of its component tissues and vessels; and that even the components of these components are severally increasing and passing into more definitely heterogeneous structures. But we have not duly remarked that while each individual is developing, the society of which he is an insignificant unit is developing too; that while the aggregate mass forming a society is integrating and becoming more definitely heterogeneous, so, too, that total aggregate, the Earth, is continuing to integrate and differentiate; that while the Earth, which in bulk is not a millionth of the Solar System, progresses towards its more concentrated structure, the Solar System similarly progresses.

So understood, Evolution becomes not one in principle only, but one in fact. There are not many metamorphoses similarly carried on, but there is a single metamorphosis universally progressing, wherever the reverse metamorphosis has not set in. In any locality, great or small, where the occupying matter acquires an appreciable individuality, or distinguishableness from other matter, there Evolution goes on; or rather, the acquirement of this appreciable individuality is the commencement of Evolution. And this holds regardless of the size of the aggregate, and regardless of its inclusion in other aggregates.

§ 189. After making them, we saw that the inductions which, taken together, establish the law of Evolution, do not, so long as they remain inductions, form that whole rightly named Philosophy; nor does even the foregoing passage of these inductions from agreement into identity suffice to produce the unity sought. For, as was pointed out at the time, to unify the truths thus reached with other truths, they must be deduced from the Persistence of Force. Our next step, therefore, was to show why, Force being persistent, the transformation which Evolution shows us necessarily results.

The first conclusion was, that any finite homogeneous aggregate must lose its homogeneity, through the unequal exposures of its parts to incident forces, and that the imperfectly homogeneous must

lapse into the decidedly non-homogeneous. It was pointed out that the production of diversities of structure by diverse forces, and forces acting under diverse conditions, has been illustrated in astronomic evolution; and that a like connexion of cause and effect is seen in the large and small modifications undergone by our globe. The early changes of organic germs supplied further evidence that unlikenesses of structure follow unlikenesses of relations to surrounding agencies—evidence enforced by the tendency of the differently-placed members of each species to diverge into varieties. And we found that the contrasts, political and industrial, which arise between the parts of societies, serve to illustrate the same principle. The instability of the relatively homogeneous thus everywhere exemplified, we saw also holds in each of the distinguishable parts into which any whole lapses; and that so the less heterogeneous tends continually to become more heterogeneous.

A further step in the inquiry disclosed a secondary cause of increasing multiformity. Every differentiated part is not simply a seat of further differentiations, but also a parent of further differentiations; since in growing unlike other parts, it becomes a centre of unlike reactions on incident forces, and by so adding to the diversity of forces at work, adds to the diversity of effects produced. This multiplication of effects proved to be similarly traceable throughout all Nature—in the actions and reactions that go on throughout the Solar System, in the never-ceasing geologic complications, in the involved changes produced in organisms by new influences, in the many thoughts and feelings generated by single impressions, and in the ever-ramifying results of each additional agency brought to bear on a society. To which was joined the corollary that the multiplication of effects advances in a geometrical progression along with advancing heterogeneity.

Completely to interpret the structural changes constituting Evolution, there remained to assign a reason for that increasingly-distinct demarcation of parts, which accompanies the production of differences among parts. This reason we discovered to be the segregation of mixed units under the action of forces capable of moving them. We saw that when unlike incident forces have made the parts of an aggregate unlike in the natures of their component units, there necessarily arises a tendency to separation

of the dissimilar units from one another, and to a clustering of those units which are similar. This cause of the definiteness of the local integrations which accompany local differentiations turned out to be likewise exemplified by all kinds of Evolution—by the formation of celestial bodies, by the moulding of the Earth's crust, by organic modifications, by the establishment of mental distinctions, by the genesis of social divisions.

At length, to the query whether these processes have any limit, there came the answer that they must end in equilibrium. That continual division and subdivision of forces, which changes the uniform into the multiform and the multiform into the more multiform, is a process by which forces are perpetually dissipated; and dissipation of them, continuing as long as there remain any forces unbalanced by opposing forces, must end in rest. It was shown that when, as happens in aggregates of various orders, many movements go on together, the earlier dispersion of the smaller and more resisted movements, establishes moving equilibria of different kinds: forming transitional stages on the way to complete equilibrium. And further inquiry made it apparent that for the same reason, these moving equilibria have certain self-conserving powers; shown in the neutralization of perturbations, and in the adjustment to new conditions. This general principle of equilibration, like the preceding general principles, was traced throughout all forms of Evolution—astronomic, geologic, biologic, mental, and social. And our concluding inference was, that the penultimate stage of equilibration in the organic world, in which the extremest multiformity and most complex moving equilibrium are established, must be one implying the highest state of humanity.

But the fact which here chiefly concerns us is that each of these laws of the re-distribution of Matter and Motion, was found to be a derivative law—a law deducible from the fundamental law. The Persistence of Force being granted, there follow as inevitable inferences "The Instability of the Homogeneous" and "The Multiplication of Effects"; while "Segregation" and "Equilibration" also become corollaries. And on thus discovering that the processes of change grouped under these titles are so many different aspects of one transformation, determined by an ultimate necessity, we arrive at a complete unification of them—a synthesis

in which Evolution in general and in detail becomes known as an implication of the law that transcends proof. Moreover, in becoming thus unified with one another the complex truths of Evolution become simultaneously unified with those simpler truths shown to have a like origin—the equivalence of transformed forces, the movement of every mass and molecule along its line of least resistance, and the limitation of its motion by rhythm. Which further unification brings us to a conception of the entire plexus of changes presented by each concrete phenomenon, and by the aggregate of concrete phenomena, as a manifestation of one fundamental fact—a fact shown alike in the total change and in all the separate changes composing it.

§ 190. Finally we turned to contemplate, as exhibited throughout Nature, that process of Dissolution which forms the complement of Evolution, and which, at some time or other, undoes what Evolution has done.

Quickly following the arrest of Evolution in aggregates that are unstable, and following it at periods often long delayed but reached at last in the stable aggregates around us, we saw that even to the vast aggregate of which all these are parts—even to the Earth as a whole—Dissolution must eventually come. Nay we even saw grounds for the belief that local assemblages of those far vaster masses we know as stars will eventually be dissipated: the question remaining unanswered whether our Sidereal System as a whole may not at a time beyond the reach of finite imagination share the same fate. While inferring that in many parts of the visible universe dissolution is following evolution, and that throughout these regions evolution will presently recommence, the question whether there is an alternation of evolution and dissolution in the totality of things is one which must be left unanswered as beyond the reach of human intelligence.

If, however, we lean to the belief that what happens to the parts will eventually happen to the whole, we are led to entertain the conception of Evolutions that have filled an immeasurable past and Evolutions that will fill an immeasurable future. We can no longer contemplate the visible creation as having a definite beginning or end, or as being isolated. It becomes unified with all

existence before and after; and the Force which the Universe presents, falls into the same category with its Space and Time, as admitting of no limitation in thought.

§ 191. This conception is congruous with the conclusion reached in Part I., where we dealt with the relation between the Knowable and the Unknowable.

It was there shown by analysis of both religious and scientific ideas, that while knowledge of the Cause which produces effects on consciousness is impossible, the existence of a Cause for these effects is a datum of consciousness. Belief in a Power which transcends knowledge is that fundamental element in Religion which survives all its changes of form. This inexpugnable belief proved to be likewise that on which all exact Science is based. And this is also the implication to which we are now led back by our completed synthesis. The recognition of a persistent Force, ever changing its manifestations but unchanged in quantity throughout all past time and all future time, is that which we find alone makes possible each concrete interpretation, and at last unifies all concrete interpretations.

Towards some conclusion of this order, inquiry, scientific, metaphysical, and theological, has been, and still is, manifestly advancing. The coalescence of polytheistic conceptions into the monotheistic conception, and the reduction of the monotheistic conception to a more and more general form, in which personal superintendence becomes merged in universal immanence, clearly shows this advance. It is equally shown in the fading away of old theories about "essences," "potentialities," "occult virtues," &c.; in the abandonment of such doctrines as those of "Platonic Ideas," "Pre-established Harmonies," and the like; and in the tendency towards the identification of Being as present in consciousness with Being as otherwise conditioned beyond consciousness. Still more conspicuous is it in the progress of Science, which, from the beginning, has been grouping isolated facts under laws, uniting special laws under more general laws, and so reaching on to laws of higher and higher generality; until the conception of universal laws has become familiar to it.

Unification being thus the characteristic of developing thought

of all kinds, and eventual arrival at unity being fairly inferable, there arises yet a further support to our conclusion. Since, unless there is some other and higher unity, the unity we have reached must be that towards which developing thought tends.

Let no one suppose that any such implied degree of trustworthiness is alleged of the various minor propositions brought in illustration of the general argument. Such an assumption would be so manifestly absurd that it seems scarcely needful to disclaim it. But the truth of the doctrine as a whole, is unaffected by errors in the details of its presentation. If it can be shown that the Persistence of Force is not a datum of consciousness; or if it can be shown that the several laws of force above specified are not corollaries from it; or if it can be shown that, given these laws, the re-distribution of Matter and Motion does not necessarily proceed as described; then, indeed, it will be shown that the theory of Evolution has not the high warrant claimed for it. But nothing short of this can invalidate the general conclusions arrived at.

§ 193. If these conclusions be accepted—if it be agreed that the phenomena going on everywhere are parts of the general process of Evolution, save where they are parts of the reverse process of Dissolution; then we may infer that all phenomena receive their complete interpretation, only when recognised as parts of these processes. Whence it follows that the limit towards which Knowledge advances can be reached only when the formulæ of these processes are so applied as to yield interpretations of phenomena in general. But this is an ideal which the real must ever fall short of.

For, true though it may be that all phenomenal changes are direct or indirect results of the persistence of force, the proof that they are such can never be more than partially given. Scientific progress is progress in that adjustment of thought to things which we saw is going on, and must continue to go on, but which can never arrive at anything like perfection. Still, though Science can never be reduced to this form, and though only at a far distant time can it be brought anywhere near it, a good deal may even now be done in the way of approximation.

Of course, what may now be done cannot be done by any single individual. No one can possess that encyclopædic information required for rightly organizing even the truths already established. Nevertheless, as all organization, beginning in faint and blurred outlines, is completed by successive modifications and additions, advantage may accrue from an attempt, however rude, to reduce the facts now accumulated—or rather certain classes of them—to something like co-ordination. Such must be the plea for the several volumes which are to succeed this: dealing with the respective divisions of what we distinguished at the outset as Special Philosophy.

§ 194. A few closing words must be said concerning the general bearings of the doctrines that are now to be further developed.

Though it is impossible to prevent misrepresentations, especially when the questions involved are of a kind that excite so much *animus*, yet to guard against them as far as may be, it will be well to make a succinct and emphatic re-statement of the Philosophico-Religious doctrine which pervades the foregoing pages.

Over and over again it has been shown in various ways, that the deepest truths we can reach are simply statements of the widest uniformities in our experiences of the relations of Matter, Motion, and Force; and that Matter, Motion, and Force are but symbols of the Unknown Reality. A Power of which the nature remains for ever inconceivable, and to which no limits in Time or Space can be imagined, works in us certain effects. These effects have certain likenesses of kind, the most general of which we class together under the names of Matter, Motion, and Force; and between these effects there are likenesses of connexion, the most constant of which we class as laws of the highest certainty. Analysis reduces these several kinds of effect to one kind of effect; and these several kinds of uniformity to one kind of uniformity. And the highest achievement of Science is the interpretation of all orders of phenomena, as differently-conditioned manifestations of this one kind of effect, under differently-conditioned modes of this one kind of uniformity. But when Science has done this, it has done nothing more than systematize our experiences, and has in no degree extended the limits of our

experiences. We can say no more than before, whether the uniformities are as absolutely necessary as they have become to our thought relatively necessary. The utmost possibility for us is an interpretation of the process of things as it presents itself to our limited consciousness; but how this process is related to the actual process we are unable to conceive, much less to know. Similarly, it must be remembered that while the connexion between the phenomenal order and the ontological order is for ever inscrutable; so is the connexion between the conditioned forms of being and the unconditioned form of being for ever inscrutable. The interpretation of all phenomena in terms of Matter, Motion, and Force, is nothing more than the reduction of our complex symbols of thought to the simplest symbols; and when the equation has been brought to its lowest terms the symbols remain symbols still. Hence the reasonings contained in the foregoing pages afford no support to either of the antagonist hypotheses respecting the ultimate nature of things. As before implied, their implications are no more materialistic than they are spiritualistic; and no more spiritualistic than they are materialistic. The establishment of correlation and equivalence between the forces of the outer and the inner worlds, serves to assimilate either to the other, according as we set out with the one or the other term. But he who rightly interprets the doctrine contained in this work will see that neither of them can be taken as ultimate. He will see that though the relation of subject and object renders necessary to us these antithetical conceptions of Spirit and Matter; the one is no less than the other to be regarded as but a sign of the Unknown Reality which underlies both.

THE END.

# APPENDICES

# APPENDIX A

## NOTE TO CHAPTERS XVII AND XIX

A conception is certain to bear some marks of its genealogy. An instance is disclosed on tracing back the formula of Evolution to its incipient stages.

If without external influence it had developed from the germ contained in *Social Statics*, where emphasis was laid on the truth that organisms and societies are similar in this, that they at first consist of like parts performing like functions and afterwards consist of unlike parts performing unlike functions (implying increase of multiformity), the conception perhaps eventually reached would have taken a shape in which the progressing division of labour would have been conspicuous. As it happened, its incipient shape was changed by the generalization of von Baer, that every individual organism in the course of its development advances from the homogeneous to the heterogeneous. Abstract as these words are, they presented the truth previously recognized, in a form which permitted extension of it from organic phenomena to inorganic phenomena. But they unawares carried with them certain implications that unduly affected the subsequent thoughts. The need for brevity had doubtless in part fixed von Baer's expression, and for his purpose qualification was unimportant: there was no need for saying that the homogeneity referred to is not absolute. Hence when adopting the word and extending its application from the physical to the psychical, and then to other forms of existence than the organic, there did not occur to me the necessity for excluding the thought of absoluteness. It is true that from time to time, as at the close of § 149 and in a note on page 265, and elsewhere, I indicated the relative sense in which the word was to be understood;

but as it was habitually used without repeating this warning, the door was left open for misinterpretation. It has been assumed that I am committed to the idea of absolute homogeneity, though I have positively excluded the assumption. Evidently, in view of probable criticisms, the phrase "relative homogeneity" should have been used throughout.

Those further traits in the development of every embryo which were not recognized by von Baer as going along with the increasing heterogeneity—the increasing coherence and increasing definiteness—are of course to be understood as having this same relativity throughout their applications to the inorganic and the super-organic as well as the organic.

Thus the transformation we call Evolution must be regarded as falling between two ideal limits, neither of which is reached: is not to be thought of as beginning with the one and ending with the other. There must always be recognized, in the interpretation of its formula, that relativity which, as repeatedly shown, characterizes all our knowledge.

The way in which a further misapprehension is apt to be produced will best be shown by some analogies.

After sunset, Venus, becoming visible, quickly draws attention; but when, presently, stars cover the heavens, the eyes are not specially fixed by any one of them. In a room lined by a flower-patterned paper, you observe no flower in particular; but if a flower be cut out and stuck on a whitewashed wall it will attract your gaze the moment you enter. A kindred effect is illustrated on contemplating the end of a line. Contrasted as this is with the empty space beyond, it impresses itself on consciousness in a greater degree than does any other portion of the line.

The psychological truth thus exemplified, whence results a fundamental principle of fine art (for artistic achievement of every kind mainly depends on due adjustment of contrasts), underlies also the art of exposition. Irrespective of their logical dependence, connected statements affect differently the minds of recipients according to the order among the impressions given: some of them gaining effectiveness by virtue of their positions. I perceive that, as a consequence, the title "The Instability of the Homogeneous" is

liable to mislead. It refers to one end of a long series of phenomena, and its place, by giving it more impressiveness than other parts of the series have, makes possible a wrong conception. The chapter bearing this title aims to show why, throughout all orders of existences, there *must* go on a continual lapse into a more heterogeneous state, such as we had seen *does* go on. Of course to prove that all aggregates conform to this law, it was needful to begin with aggregates having no heterogeneity. But this putting a state of homogeneity in the foreground, tends to produce the idea that it is more unstable than other states. Further, it leaves an opening for the idea that the validity of the argument depends on the existence of a state of homogeneity—the idea that if homogeneity nowhere exists, or has existed, the argument lapses. Such ideas were not intended to be given, nor are they implied; and, as already pointed out, they have been from time to time excluded. The aim was simply to show that go back as far as we may, even to a homogeneity which is unknown but only imaginable, the law necessarily holds.

Contemplated from a higher point of view, this law may be recognized as a corollary from the truth that change is universal and unceasing. From the centre of our system down to a microbe, each aggregate is subject to incident forces derived from other aggregates large or small: even the Sun being affected by the planets. Nowhere is there that sheltering from inner and outer influences which is implied by absolute rest.

In aggregates of some kinds incident forces produce changes that are evanescent. As was pointed out in § 102, aëriform masses and liquid masses, in which re-distributions have been set up by outer actions, show no subsequent effects: their components have not the required cohesion. But all other aggregates are liable to have their components permanently affected in arrangement, or form, or quality. If, now, instead of contemplating a modification produced in an aggregate at one time only, we contemplate modifications produced time after time, usually unlike as their causes are unlike, we see that there must result a perpetual superposing of modifications upon modifications. We see that the continual increase of heterogeneity is a necessary consequence—that the transformation

of the homogeneous into the heterogeneous, and of this into the more heterogeneous, is the necessary effect of these superpositions. Thus no special instability characterizes the homogeneous. It is simply that changes wrought in it are more conspicuous than are those wrought in anything already heterogeneous; and also, that, standing at one end of the series of metamorphoses, it gains more attention than the rest. This prominence has been caused by the needs of the exposition. To show the universality of this perpetual increase of structure, it was requisite to begin with the structureless.

# APPENDIX B

## DEALING WITH CERTAIN CRITICISMS

One way of estimating the validity of a critic's judgments, is that of studying his mental peculiarities as generally displayed. If he betrays idiosyncrasies of thought in his writings at large, it may be inferred that these idiosyncrasies possibly, if not probably, give a character to the verdicts he passes upon the productions of others. I am led to make this remark by considering the probable connexion between Professor Tait's habit of mind as otherwise shown, and as shown in the opinion he has tacitly expressed respecting the formula of Evolution.

Daily carrying on experimental researches, Professor Tait is profoundly impressed with the supreme value of the experimental method; and has reached the conviction that by it alone can any physical knowledge be gained. Though he calls the ultimate truths of physics "axioms," yet, not very consistently, he alleges that only by observation and experiment can these "axioms" be known as such. Passing over this inconsistency, however, we have here to note the implied proposition that where no observation or experiment is possible, no physical truth can be established; and, indeed, that in the absence of any possibility of experiment or observation there is no basis for any physical belief at all. Now *The Unseen Universe,* a work written by him in conjunction with Professor Balfour Stewart, contains an elaborate argument concerning the relations between the Universe which is visible to us and an invisible Universe. This argument, carried on in pursuance of physical laws established by converse with the Universe we know, extends them to the Universe we do not know: the law of the Conservation of Energy, for example, being regarded as common to the two, and the principle of Continuity, which is traced among perceptible phenomena, being assumed to hold likewise of the imperceptible. On the strength of these reasonings, conclusions are drawn which are considered as at least probable: support is found for certain theological beliefs. Now, clearly, the relation between the seen and the unseen Universes cannot be the subject of any observation or experiment; since, by the definition of it, one term of the relation is absent. If we have, then, no warrant for

asserting a physical axiom save as a generalization of results of experiments—if, consequently, where no observation or experiment is possible, reasoning after physical methods can have no place; then there can be no basis for any conclusion respecting the physical relations of the seen and the unseen Universes. Not so, however, concludes Professor Tait. He thinks that while no validity can be claimed for our judgments respecting perceived forces, save as experimentally justified, some validity can be claimed for our judgments respecting unperceived forces, where no experimental justification is possible.

The peculiarity thus exhibited in Professor Tait's general thinking, is exhibited also in some of his thinking on those special topics with which he is directly concerned as a Professor of Physics. An instance was given by Professor Clerk Maxwell when reviewing, in *Nature* for July 3, 1879, the new edition (1879) of Thomson and Tait's *Treatise on Natural Philosophy*. Professor Clerk-Maxwell writes:—

"Again at p. 222, the capacity of the student is called upon to accept the following statement:—

'Matter has an innate power of resisting external influences, so that every body, as far as it can, remains at rest or moves uniformly in a straight line.'

Is it a fact that 'matter' has any power, either innate or acquired, of resisting external influences?"

And to Professor Clerk Maxwell's question thus put, the answer of one not having a like mental peculiarity with Professor Tait, must surely be—No.

But the most remarkable example of Professor Tait's mode of thought, as exhibited in his own department, is contained in a lecture which he gave at Glasgow when the British Association last met there (see *Nature*, September 21, 1876)—a lecture given for the purpose of dispelling certain erroneous conceptions of force commonly entertained. Asking how the word force "is to be correctly used" he says:—

"Here we cannot but consult Newton. The sense in which he uses the word 'force,' and therefore the sense in which we must continue to use it if we desire to avoid intellectual confusion, will appear clearly from a brief consideration of his simple statement of the laws of motion. The first of these laws is: *Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it is compelled by impressed forces to change that state.*"

Thus Professor Tait quotes, and fully approves, that conception of force which regards it as something which changes the state of a body. Later on in the course of his lecture, after variously setting forth his views of how force is rightly to be conceived, he says "force is the rate at which an agent does work per unit of length." Now let us compare these two definitions of force. It is first, on the authority of Newton emphatically endorsed, said to be that which changes the state of a body. Then it is said to be the rate at which an agent does work (doing work being equivalent to changing a body's state). In the one case, therefore, force itself is the agent which does the work or

changes the state; in the other case, force is the rate at which some other agent does the work or changes the state. How are these statements to be reconciled? Otherwise put the difficulty stands thus:—force is that which changes the state of a body; force is a rate, and a rate is a relation (as between time and distance, interest and capital); therefore a relation changes the state of a body. A relation is no longer a *nexus* among phenomena, but becomes a producer of phenomena. Whether Professor Tait succeeded in dispelling "the wide-spread ignorance as to some of the most important elementary principles of physics"—whether his audience went away with clear ideas of the "much abused and misunderstood term" force, the report does not tell us.

Let us pass now from these illustrations of Professor Tait's judgment as exhibited in his special department, to the consideration of his judgment on a wider question here before us—the formula of Evolution. In *Nature* for July 17, 1879, while reviewing Sir Edmund Beckett's *Origin of the Laws of Nature* and praising it, he says of the author:—

"He follows out in fact, in his own way, the hint given by a great mathematician (Kirkman) who made the following exquisite translation of a well-known definition: —Evolution is a change from an indefinite, incoherent, homogeneity to a definite, coherent, heterogeneity, through continuous differentiations and integrations.*
[*Translation into plain English.*] Evolution is a change from a nohowish, untalkaboutable, all-alikeness, to a somehowish and in-general-talkaboutable not-all-alikeness, by continuous somethingelseifications, and sticktogetherations."

Professor Tait, proceeding then to quote from Sir Edmund Beckett's book passages in which, as he thinks, there is a kindred tearing off of disguises from the expressions used by other authors, winds up by saying—"When the purposely vague statements of the materialists and agnostics are thus stripped of the tinsel of high-flown and unintelligible language, the eyes of the thoughtless who have accepted them on authority (!) are at last opened, and they are ready to exclaim with Titania, 'Methinks I was enamoured of an ass.'" And that Mr Kirkman similarly believes that his travesty proves the formula of Evolution to be meaningless, is shown by the sentence which follows it—"Can any man show that my translation is unfair?"

One would have thought that Mr. Kirkman and Professor Tait, however narrowly they limited themselves to their special lines of inquiry, could hardly have avoided observing that in proportion as scientific terms express wider generalities, they necessarily lose that

* A conscientious critic usually consults the latest edition of the work he criticizes, so that the author may have the benefit of any corrections or alterations he has made. Apparently Mr. Kirkman does not think such a precaution needful. Publishing in 1876 his *Philosophy without Assumptions*, from which the above passage is taken, he quotes from the first edition of *First Principles* published in 1862; though in the edition of 1867, and all subsequent ones, the definition is, in expression, considerably modified—two of the leading words being no longer used.

vividness of suggestion which words of concrete meanings have; and therefore to the uninitiated seem vague, or even empty. If Professor Tait enunciated to a rustic the physical axiom, "action and reaction are equal and opposite," the rustic might not improbably fail to form any corresponding idea. And he might, if his self-confidence were akin to that of Mr. Kirkman, conclude that where he saw no meaning there could be no meaning. Further, if, after the axiom had been brought partially within his comprehension by an example, he were to laugh at the learned words used and propose to say instead—"shoving and back-shoving are one as strong as the other;" it would possibly be held by Professor Tait that this way of putting it is hardly satisfactory. If he thought it worth while to enlighten the rustic, he might perhaps point out to him that his statement did not include all the facts—that not only shoving and back-shoving, but also pulling and back-pulling, are one as strong as the other. Supposing the rustic were not too conceited, he might eventually be taught that the abstract, and to him seemingly vague, formula "action and reaction are equal and opposite," was chosen because by no words of a more specific kind could be expressed the truth in its entirety. Professor Tait however, and Mr. Kirkman, though the physical and mathematical terms they daily employ are so highly abstract as to prove meaningless to those who are unfamiliar with the concrete facts covered by them, seem not to have drawn any general inference from this habitual experience. For had they done so, they must have been aware that a formula expressing all orders of changes in their general course—astronomic, geologic, biologic, psychologic, sociologic—could not possibly be framed in any other than words of the highest abstractness. Perhaps there may come the rejoinder that they do not believe any such universal formula is possible. Perhaps they will say that the on-going of things as shown in our planetary system, has nothing in common with the on-going of things which has brought the Earth's crust to its present state, and that this has nothing in common with the on-going of things which the growths and actions of living bodies show us; although, considering that the laws of molar motion and the laws of molecular action are proved to hold true of them all, it requires considerable courage to assert that the modes of co-operation of the physical forces in these several regions of phenomena present no traits in common. But unless they allege that there is one law for the re-distribution of matter and motion in the heavens, and another law for the re-distribution of matter and motion in the Earth's inorganic masses, and another law for its organic masses—unless they assert that the transformation everywhere in progress follows here one method and there another; they must admit that the proposition which expresses the general course of the transformation can do it only in terms remote in the extremest degree from words suggesting definite objects and actions.

After noting the unconsciousness thus betrayed by Mr. Kirkman and Professor Tait, that the expression of highly abstract truths necessitates highly abstract words, we may go on to note a scarcely less remarkable anomaly of thought shown by them. Mr. Kirkman appears to think, and Professor Tait apparently agrees with him in thinking, that when one of these abstract words coined from Greek or Latin roots is transformed into an uncouth-looking combination of equivalents of Saxon, or rather old English, origin, what they regard as its misleading glamour is thereby dissipated and its meaninglessness made manifest. We may conveniently observe the nature of Mr. Kirkman's belief, by listening to an imaginary addition to that address before the Literary and Philosophical Society of Liverpool, in which he first set forth the leading ideas of his volume; and we may fitly, in this imaginary addition, adopt the manner in which he delights.

"Observe, gentlemen," we may suppose him saying, "I have here the yolk of an egg. The evolutionists, using their jargon, say that one of its characters is 'homogeneity;' and if you do not examine your thoughts, perhaps you may think that the word conveys some idea. But now if I translate it into plain English and say that one of the characters of this yolk is 'all-alikeness,' you at once perceive how nonsensical is their statement. You see that the substance of the yolk is not all-alike, and that therefore all-alikeness cannot be one of its attributes. Similarly with the other pretentious term 'heterogeneity,' which, according to them, describes the state things are brought to by what they call evolution. It is mere empty sound, as is manifest if I do but transform it, as I did the other, and say instead 'not-all-alikeness.' For on showing you this chick into which the yolk of the egg turns, you will see that 'not-all-alikeness' is a character which cannot be claimed for it. How can any one say that the parts of the chick are not-all-alike? Again, in their blatant language we are told that evolution is carried on by continuous 'differentiations'; and they would have us believe that this word expresses some fact. But if we put instead of it 'somethingelseifications' the delusion they try to practise on us becomes clear. How can they say that while the parts have been forming themselves, the heart has been becoming something else than the stomach, and the leg something else than the wing, and the head something else than the tail? The like manifestly happens when for 'integrations' we read 'sticktogetherations:' what sense the term might seem to have becomes obvious nonsense when the substituted word is used. For nobody dares assert that the parts of the chick stick together any more than do the parts of the yolk. I need hardly show you that now when I take a portion of the yolk between my fingers and pull, and now when I take any part of the chick, as the leg, and pull, the first resists just as much as the last—the last does not stick together any more than the first; so that there

has been no progress in 'sticktogetherations.' And thus, gentlemen, you perceive that these big words which, to the disgrace of the Royal Society, appear even in papers published by it, are mere empty bladders which these would-be philosophers use to buoy up their ridiculous doctrines."

There is a further curious mental trait exhibited by Mr. Kirkman and which Professor Tait appears to have in common with him. Very truly it has been remarked that there is a great difference between disclosing the absurdities contained *in* a thing and piling absurdities *upon* it; and a remark to be added is that some minds appear incapable of distinguishing between intrinsic absurdity and extrinsic absurdity. The case before us illustrates this remark; and at the same time shows us how analytical faculties of one kind may be constantly exercised without strengthening analytical faculties of another kind—how mathematical analysis may be daily practised without any skill in psychological analysis being acquired. For if these gentlemen had analyzed their own thoughts to any purpose, they would have known that incongruous juxtapositions may, by association of ideas, suggest characters that do not at all belong to the things juxtaposed. Did Mr. Kirkman ever observe the result of putting a bonnet on a nude statue? If he ever did, and if he then reasoned after the manner exemplified above, he doubtless concluded that the obscene effect belonged intrinsically to the statue, and only required the addition of the bonnet to make it conspicuous. The alternative conclusion, however, which perhaps most will draw, is that not in the statue itself was there anything of an obscene suggestion, but that this effect was purely adventitious: the bonnet, connected in daily experience with living women, calling up the thought of a living woman with the head dressed but otherwise naked. Similarly though, by clothing an idea in words which excite a feeling of the ludicrous by their oddity, any one may associate this feeling of the ludicrous with the idea itself, yet he does not thereby make the idea ludicrous; and if he thinks he does, he shows that he has not practised introspection to much purpose.

By way of a lesson in mental discipline, it may be not uninstructive here to note a curious kinship of opinion between these two mathematicians and two litterateurs. At first sight it appears strange that men whose lives are passed in studies so absolutely scientific as those which Professor Tait and Mr. Kirkman pursue, should, in their judgments on the formula of Evolution, be at one with two men of exclusively literary culture—a North American Reviewer and Mr. Matthew Arnold. In the *North American Review*, vol. 120 page 202, a critic, after quoting the formula of Evolution, says:—"This may be all true, but it seems at best rather the blank form for a universe than anything corresponding to the actual world about us." On which the comment may be that one who had studied celestial mechanics as

much as the reviewer has studied the general course of transformations, might similarly have remarked that the formula—"bodies attract one another directly as their masses and inversely as the squares of their distances," was at best but a blank form for solar systems and sidereal clusters. With this parenthetical comment I pass to the fact above hinted, that Mr. Matthew Arnold obviously coincides with the reviewer's estimate of the formula. In Chapter V. of his work *God and the Bible*, when preparing the way for a criticism on German theologians as losing themselves in words, he quotes a saying from Homer. This he introduces by remarking that it "is not at all a grand one. We are almost ashamed to quote it to readers who may have come fresh from the last number of the *North American Review*, and from the great sentence there quoted as summing up Mr. Herbert Spencer's theory of evolution:—'Evolution is &c.' Homer's poor little saying comes not in such formidable shape. It is only this:—*Wide is the range of words! words may make this way or that way.*" And then he proceeds with his reflections upon German logomachies. All of which makes it manifest that, going out of his way, as he does, to quote this formula from the *North American Review*, he intends tacitly to indicate his agreement in the reviewer's estimate of it.

That these two men of letters, like the two mathematicians, are unable to frame ideas answering to the words in which evolution at large is expressed, seems manifest. In all four the verbal symbols used call up either no images, or images of the vaguest kinds, which, grouped together, form but the most shadowy thoughts. If, now, we ask what is the common trait in the education and pursuits of all four, we see it to be lack of familiarity with those complex processes of change which the concrete sciences bring before us. The men of letters, in their early days dieted on grammars and lexicons, and in their later days occupied with *belles lettres*, Biography, and a History made up mainly of personalities, are by their education and course of life left almost without scientific ideas of a definite kind. The universality of physical causation—the interpretation of all things in terms of a never-ceasing re-distribution of matter and motion, is naturally to them an idea utterly alien. The mathematician, too, and the mathematical physicist, occupied exclusively with the phenomena of number, space, and time, or, in dealing with forces, dealing with them in the abstract, carry on their researches in such ways as may, and often do, leave them quite unconscious of the traits exhibited by the general transformations which things, individually and in their totality, undergo. In a chapter on "Discipline" in the *Study of Sociology*, I have commented upon the uses of the several groups of Sciences—Abstract, Abstract-Concrete, and Concrete—in cultivating different powers of mind; and have argued that while for complete preparation, the discipline of each group of sciences is indispensable, the discipline of any one group alone, or any two groups, leaves certain

defects of judgment. Especially have I contrasted the analytical habit of thought which study of the Abstract and Abstract-Concrete Sciences produces, with the synthetical habit of thought, produced by study of the Concrete Sciences. And I have exemplified the defects of judgment to which the analytical habit, unqualified by the synthetical habit, leads. Here we meet with a striking illustration. Scientific culture of the analytical kind, almost as much as absence of scientific culture, leaves the mind bare of those ideas with which the Concrete Sciences deal. Exclusive familiarity with the *forms* and *factors* of phenomena no more fits men for dealing with the *products* in their totalities, than does mere literary study.

An objection made to the formula of evolution by a sympathetic critic, Mr. T. E. Cliffe Leslie, calls for notice. It is urged in a spirit widely different from that displayed by Mr. Kirkman and his applauder Professor Tait; and it has an apparent justification. Indeed many readers who before accepted the formula of Evolution in full, will, after reading Mr. Cliffe Leslie's comments, agree with him in thinking that it is to be taken with the qualifications he points out. We shall find, however, that a clearer apprehension of the meanings of the words used, and a clearer apprehension of the formula in its totality, excludes the criticisms Mr. Leslie makes.

In the first place he dissociates from one another those traits of Evolution which I have associated, and which I have alleged to be true only when associated. He quotes me as saying that a change from the homogeneous to the heterogeneous characterizes all evolution; and he puts this at the outset of his criticism as though I made this change the primary characteristic. But if he will refer to *First Principles,* Part II. chap. 14 (in the second and subsequent editions) he will find it shown that under its *primary* aspect, Evolution "is a change from a less coherent form to a more coherent form, consequent on the dissipation of motion and integration of matter." The next chapter contains proofs that the change from homogeneity to heterogeneity is a *secondary* change, which, when conditions allow, accompanies the change from the incoherent to the coherent. At the beginning of the chapter after that, come the sentences—"But does this generalization express the whole truth? Does it include everything essentially characterizing Evolution and exclude everything else? . . . A critical examination of the facts will show that it does neither." And the chapter then goes on to show that the change is from an *indefinite* incoherent homogeneity to a *definite* coherent heterogeneity. Further qualifications contained in a succeeding chapter, bring the formula to this final form—"Evolution is an integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation."

Now if these various traits of the process of Evolution are kept simultaneously in view, it will be seen that most of Mr. Cliffe Leslie's objections fail to apply. He says :—

"The movement of language, law, and political and civil union, is for the most part in an opposite direction. In a savage country like Africa, speech is in a perpetual flux, and new dialects spring up with every swarm from the parent hive. In the civilized world the unification of language is rapidly proceeding."

Here two different ideas are involved—the evolution of a language considered singly, and the evolution of languages considered as an aggregate. Nothing which he says implies that any one language becomes, during its evolution, less heterogeneous. The disappearance of dialects is not a progress towards the homogeneity of a language, but is the final triumph of one variety of a language over the other varieties, and the extinction of them: the conquering variety meanwhile becoming within itself more heterogeneous. This, too, is the process which Mr. Leslie refers to as likely to end in an extinction of the Celtic languages. Advance towards homogeneity would be shown if the various languages in Europe, having been previously unlike, were, while still existing, to become gradually more like. But the supplanting of one by another, or of some by others, no more implies any tendency of languages to become alike, than does the supplanting of species, genera, orders, and classes of animals, one by another, during the evolution of life, imply the tendency of organisms to assimilate in their natures. Even if the most heterogeneous creature, Man, should overrun the Earth and extirpate the greater part of its other inhabitants, it would not imply any tendency towards homogeneity in the proper sense. It would remain true that organisms tend perpetually towards heterogeneity, individually and as an assemblage. Of course if all kinds but one were destroyed, they could no longer display this tendency. Display of it would be limited to the remaining kind, which would continue, as now, to show it in the formation of local varieties, becoming gradually more divergent; and the like is true of languages.

In the next case Mr. Leslie identifies progressing unification with advance towards homogeneity. His words are .—

"Already Europe has nearly consolidated itself into a Heptarchy, the number of states into which England itself was once divided ; and the result of the American War exemplifies the prevalence of the forces tending to homogeneity over those tending to heterogeneity."

To this the reply is that these cases exemplify, rather, the prevalence of the forces which change the incoherent into the coherent—which effect integration. That is, they exemplify Evolution under its primary aspect. In the *Principles of Sociology*, Part II. chap. 3, Mr. Leslie will find numerous kindred cases brought in illustration of this law of Evolution. To which add that such integrations bring after them greater heterogeneity, not greater homogeneity. The

divisions of the Heptarchy were societies substantially like one another in their structures and activities; but the parts of the nation which correspond to them have been differentiated into parts carrying on varieties of occupations with entailed unlikenesses of structures—here purely agricultural, there manufacturing; here predominantly given to coal mining and iron smelting, there to weaving; here distinguished by scattered villages, there by clusters of large towns.

Again, it is alleged that an increasing homogeneity is shown in fashion. "Once every rank, profession, and district had a distinctive garb; now all such distinctions, save with the priest and the soldier, have almost disappeared among men." But while for a reason to be presently pointed out, there has occurred a change which has abolished one order of differences, differences of another order, far more multitudinous, have arisen. Nothing is more striking than the extreme heterogeneity of dress at the present day. As Mr. Leslie alleges, the dresses of those forming each class were once all alike; now no two dresses are alike. Within the vague limits of the current fashion, the degree of variety in women's costumes is infinite; and even men's costumes, though having average resemblances, diverge from one another in colours, materials, and detailed forms in innumerable ways.

Other instances given by Mr. Leslie concern the organizations for carrying on production and distribution. He argues that—

> 'In the industrial world a generation ago a constant movement towards a differentiation of employments and functions appeared; now some marked tendencies to their amalgamation have begun to disclose themselves. Joint Stock Companies have almost effaced all real division of labour in the wide region of trade within their operation."

Here, as before, Mr. Leslie represents amalgamation as equivalent to increase of homogeneity; whereas amalgamation is but another name for integration, which is the primary process in Evolution, and which may, and does, go along with increasing heterogeneity in the amalgamated things. It cannot be said that a Joint Stock Banking Company, with its proprietory and directors in addition to its officers, contains fewer unlike parts than does a private Banking establishment: the contrary must be said. A Railway Company has far more numerous functionaries with different duties, than had the one, or the many, coaching establishments it replaced. And then, apart from the fact that the larger aggregate of co-operators who, as a Company, carry on, say a process of manufacture, is more complex as well as more extensive; there is the fact, here chiefly to be noted, that the entire assemblage of industrial structures is, by the addition of these new structures, made more heterogeneous than before. Had all the smaller manufacturing establishments, carried on by individuals or firms, been destroyed, the contrary might have been alleged; but

as it is, we see that in addition to all the old forms there have come these new forms, making the totality of them more multiform than before. Mr. Leslie further illustrates his interpretation by saying:—

"Many of the things for sale in a village huckster's shop were formerly the subjects of distinct branches of business in a large town; now the wares in which scores of different retailers dealt, are all to be had in great establishments in New York, Paris, and London, which sometimes buy direct from the producers, thus also eliminating the wholesale dealer."

Replies akin to the preceding ones are readily made. The first is that wholesale dealers have not been at present eliminated; and cannot be so long as the ordinary shopkeepers survive, as they will certainly do. In the smaller places, forming the great majority of places, these vast establishments cannot exist; and in them, shopkeepers carrying on business as at present, will continue to necessitate wholesale dealers. Even in large places the same thing will hold. It is only people of a certain class, able to pay ready money and willing to go great distances to purchase, who frequent these large establishments. Those who live from hand to mouth, and those who prefer to buy at adjacent places, will maintain a certain proportion of shops, and the wholesale distributing organization needed for them. Again, we have to note that one of these great stores, such as Whiteley's or Shoolbred's, does not within itself display any advance towards homogeneity or de-specialization; for it is made up of many separate departments, with their separate heads, carrying on business substantially separate—all superintended by one owner. It is nothing but an aggregate of shops under one roof instead of under the many roofs covering the side of a street; and exhibits just as much heterogeneity as the shops do when arranged in line instead of massed together. That which it really illustrates is a new form of integration, which is the primary evolutionary process. And then, lastly, comes the fact that the distributing organization of the country, considered as a whole, is by the addition of these establishments made more heterogeneous than before. All the old types of trading concerns continue to exist; and here are new types added, making the entire assemblage of them more varied.

From these objections made by Mr. Leslie which I have endeavoured to show result from misapprehensions, I pass to two others which are to be met by taking account of certain complicating facts liable to be overlooked. Mr. Leslie remarks that:—

"In the early stages of social progress, again, a differentiation takes place, as Mr. Spencer has observed, between political and industrial functions, which fall to distinct classes; now a man is a merchant in the morning and a legislator at night; in mercantile business one year, and the next perhaps head of the Navy, like Mr. Goschen or Mr. W. H. Smith."

Nothing contained in this volume explains the seeming anomaly here exemplified; but anyone who turns to a chapter in the second part

of the *Principles of Sociology*, entitled "Social Metamorphoses," will there find a clue to the explanation of it; and will see that it is a phenomenon consequent on the progressing dissolution of one type and evolution of another. The doctrine of Evolution, currently regarded as referring only to the development of species, is erroneously supposed to imply some intrinsic proclivity in every species towards a higher form; and, similarly, a majority of readers make the erroneous assumption that the transformation which constitutes Evolution in its wider sense, implies an intrinsic tendency to go through those changes which the formula of Evolution expresses. But all who have fully grasped the argument of this work, will see that the process of Evolution is not necessary, but depends on conditions; and that the prevalence of it in the Universe around, is consequent on the prevalence of these conditions: the frequent occurrence of Dissolution showing us that where the conditions are not maintained, the reverse process is quite as readily gone through. Bearing in mind this truth, we shall be prepared to find that the progress of a social organism towards more heterogeneous and more definite structures of a certain type continues only as long as the actions which produce these effects continue in play. We shall expect that if these actions cease, the progressing transformation will cease. We shall infer that the particular structures which have been formed by the activities carried on, will not grow more heterogeneous and more definite; and that if other orders of activities, implying other sets of forces, commence, answering structures of another kind will begin to make their appearance, to grow more heterogeneous and definite, and to replace the first. And it will be manifest that while the transition is going on—while the first structures are dissolving and the second evolving—there must be a mixture of structures causing apparent confusion of traits. Just as during the metamorphoses of an animal which, having during its earlier existence led one kind of life, has to develop structures fitting it for another kind of life, there must occur a blurring of the old organization while the new organization is becoming distinct, leading to transitory anomalies of structure; so, during the metamorphoses undergone by a society in which the militant activities and structures are dwindling while the industrial are growing, the old and new arrangements must be mingled in a perplexing way. On reading the chapter in the *Principles of Sociology* which I have named, Mr. Leslie will see that the above facts referred to by him are interpretable as consequent on the transition from that type of regulative organization proper to militant life, to that type of regulative organization proper to industrial life; and that so long as these two modes of life, utterly alien in their natures, have to be jointly carried on, there will continue this jumbling of the regulative systems they respectively require.

The second of the objections above noted, as needing to be other-

wise dealt with than by further explanation of the formula of Evolution, concerns the increase of likeness among developing systems of Civil Law; in proof of which increase of likeness Mr. Leslie quotes Sir Henry Maine to the effect that 'all laws, however dissimilar in their infancy, tend to resemble each other in their maturity:' the implication to which Mr. Leslie draws attention, being that in respect of their laws societies become not more heterogeneous but more homogeneous. Now though in their details, systems of Law will, I think, be found to acquire as they evolve, an increasing number of differences from one another; yet in their cardinal traits it is probably true that they usually approximate. How far this militates against the formula of Evolution, we shall best see by first considering the analogy furnished by animal organisms. Low down in the animal kingdom there are simple molluscs with but rudimentary nervous systems—a ganglion or two and a few fibres. Diverging from this low type we have the great sub-kingdom constituted by the higher Mollusca and the still greater sub-kingdom constituted by the Vertebrata. As these two types evolve, their nervous systems develop; and though in the highest members of the two they remain otherwise unlike, yet they approximate in so far that each acquires great nervous centres: the large cephalopods have clustered ganglia which simulate brains. Compare, again, the Mollusca and the Articulata in respect of their vascular systems. Fundamentally unlike as these are originally, and remaining unlike as they do throughout many successive stages of ascent in these two sub-kingdoms, they nevertheless are made similar in the highest forms of both by each having a central propelling organ—a heart. Now in these and in some cases which the external organs furnish, such as the remarkable resemblance Evolution has produced between the eyes of the highest Mollusca and those of the Vertebrata, it may be said that there is implied a change towards homogeneity. No zoologist, however, would admit that these facts really conflict with the general law of Organic Evolution. As already explained, the tendency to progress from homogeneity to heterogeneity is not intrinsic but extrinsic. Structures become unlike in consequence of unlike exposures to incident forces. This is so with organisms as wholes, which, as they multiply and spread, are ever falling into new sets of conditions; and it is so with the parts of each organism. These pass from primitive likeness into unlikeness, as fast as the mode of life places them in different relations to actions—primarily external and secondarily internal; and with each successive change in mode of life new unlikenesses are superposed. One of the implications is that if in organisms otherwise different, there arise like sets of conditions to which certain parts are subject, such parts will tend towards likeness; and this is what happens with their nervous and vascular systems. Duly to coordinate the actions of all parts of an active organism, there requires a controlling apparatus; and the conditions to be fulfilled for perfect

co-ordination, are conditions common to all active organisms. Hence, in proportion as fulfilment approaches completeness in the highest organisms, however otherwise unlike their types are, this apparatus acquires in all of them certain common characters—especially extreme centralization. Similarly with the apparatus for distributing nutriment. The relatively high activity accompanying superior organization, implies great waste; great waste implies active circulation of blood; active circulation of blood implies efficient propulsion; so that a heart becomes a common need for highly evolved creatures, however otherwise unlike their structures may be. Thus is it, too, with societies. As they evolve there arise certain conditions to be fulfilled for the maintenance of social life; and in proportion as the social life becomes high, these conditions need to be more effectually fulfilled. A legal code expresses one set of these conditions. It formulates certain regulative principles to which the conduct of citizens must conform that social activities may be harmoniously carried on. And these regulative principles being in essentials the same everywhere, it results that systems of Law acquire certain general similarities as the most developed social life is approached.

These special replies to Mr. Leslie's objections are, however, but introductory to the general reply; which would be, I think, adequate even in their absence. Mr. Leslie's method is that of taking detached groups of social phenomena, as those of language, of fashion, of trade, and arguing (though as I have sought to show, not effectually) that their later transformations do not harmonize with the alleged general law of Evolution. But the real question is, not whether we find advance to a more definite coherent heterogeneity in these taken separately, but whether we find this advance in the structures and actions of the entire society. Even were it true that the law does not hold in certain orders of social processes and products, it would not follow that it does not hold of social processes and products in their totality. The law is a law of the transformation of aggregates; and must be tested by the entire assemblages of phenomena which the aggregates present. Omitting societies in states of decay and dissolution, which exhibit the converse change, and contemplating only societies which are growing, Mr. Leslie will, I think, scarcely allege of any one of them that its structures and functions do not, taken altogether, exhibit increasing heterogeneity. And if, instead of taking each society as an aggregate, he takes the entire aggregate of societies which the Earth supports, from primitive hordes up to highly civilized nations, he will scarcely deny that this entire aggregate has been becoming more various in the forms of societies it includes, and is still becoming more various.

*[Some little time after this appendix was published, Prof. Cliffe Leslie, with a candour extremely rare among critics, acknowledged that I had shown*

*his objection to be invalid, and that the Law of Evolution is not traversed by the cases he instanced. I retain this appendix, however, because the objection originally made by him may very likely be again made by others.*

*There here followed two other appendices, one dealing with a book* On Mr. Spencer's Formula of Evolution, *by Malcolm Guthrie, and the other dealing with a book by Prof. Birks,* Modern Physical Fatalism and the Doctrine of Evolution, including an examination of Mr. H. Spencer's First Principles. *As the criticisms contained in both works were based on misunderstandings and misrepresentations, and as they were not made authoritative by the positions of their writers, I have thought it needless again to reproduce these appendices.*]

# APPENDIX C

## DEALING WITH SOME CRITICISMS OF PROF. WARD

It is half instructive half amusing to observe what trivial difficulties, and even what imaginary difficulties, are urged by those who seek reasons for rejecting doctrines they dislike. Such reasons for rejecting the doctrine of Evolution as set forth in this work are of course eagerly sought by one who, resenting the conception of a fixed quantity of existence, or of force, under the forms of matter and motion, espouses the conception of Lotze that, "should the self-realization of the Idea require it," "the working elements of the world" may be varied in number and intensity.

Prof. Ward tries to show that the doctrine of the instability of the homogeneous is invalid. Let me first state this doctrine in my own words.

' The condition of homogeneity is a condition of unstable equilibrium. * * *

" It follows that not only must the homogeneous lapse into the non-homogeneous, but that the more homogeneous must tend ever to become less homogeneous [that is, more heterogeneous]. * * *

" No demurrer to the conclusions drawn can be based on the ground that perfect homogeneity nowhere exists; since, whether that state with which we commence be or be not one of perfect homogeneity, the process must equally be towards a relative heterogeneity." (§ 149.)

"One stable homogeneity only is hypothetically possible. If centres of force, absolutely uniform in their powers, were diffused with absolute uniformity through unlimited space, they would remain in equilibrium. This, however, though a verbally intelligible supposition, is one that cannot be represented in thought; since unlimited space is inconceivable. But all finite forms of the homogeneous—all forms of it which we can know or conceive, must inevitably lapse into heterogeneity." (§ 155.)

See now the comment of Prof. Ward on the view thus set forth and thus qualified.

" In truth, however, homogeneity is not necessarily instability. Quite otherwise. If the homogeneity be absolute,—that of Lord Kelvin's primordial medium, say,—then the stability will be absolute too. In other words, if ' the indefinite, incoherent homogeneity,' in which, according to Mr. Spencer, some rearrangement *must result*,

be a state devoid of all qualitative diversity and without assignable bounds, then, as we saw in discussing mechanical ideals, any 'rearrangement' can result only from external interference; it cannot begin from within." * * *

"Thus, the very first step in Mr. Spencer's evolution seems to necessitate a breach of continuity. This fatal defect," etc. (*Naturalism and Agnosticism*, i, 223.)

In the first place, then, I am contradicted by having urged against me a truth which I myself distinctly affirmed a generation ago. In the second place it is alleged that as the law of the instability of the homogeneous does not extend to an infinite aggregate, which is neither knowable nor conceivable, it is invalid. In the third place this is said to constitute a "breach of continuity," and, by "this fatal defect," my exposition of the doctrine as applying to all finite aggregates is vitiated. An analogy will best show the quality of this assertion.

"Here," says a mathematical lecturer, directing his class to a diagram, "is a curve called a parabola. It is an infinite curve, and some of its leading properties I will now explain to you." "But where is the infinite parabola?" inquires a listener: "I do not see it." "No, this parabola which I show you is not infinite, and no infinite parabola anywhere exists or has ever existed." "How, then," says the objector, "can you begin to tell us about the properties of an infinite parabola, if there is not, nor ever has been, nor can be imagined, any such thing?" And thereupon he characterizes the lecturer's propositions as so many delusions.

Besides seeking to force on me the conception of a homogeneity "without assignable bounds"—that is, infinite in extent—notwithstanding my repudiation of it, Prof. Ward seeks to force on me the implication that this homogeneity is absolute, though I have nowhere said or implied as much. He speaks of me as assuming a "pristine homogeneity," and he says "the proposal to start with complete homogeneity leads us to ask, &c." True, I have said "the absolutely homogeneous *must* lose its equilibrium, and the relatively homogeneous *must* lapse into the relatively less homogeneous." But by this statement I no more commit myself to the assertion that the absolutely homogeneous exists, or has existed, than the geometer commits himself to the assertion that there exists an infinite parabola when he points out the properties which an infinite parabola possesses. So far from implying my belief in an initial state of homogeneity, I have, in one of the passages quoted above, said that "no demurrer to the conclusions drawn can be based on the ground that perfect homogeneity nowhere exists, since whether that state with which we commence be or be not one of perfect homogeneity, the process must equally be towards a relative heterogeneity." And then, to guard myself more fully against the supposition that absolute homogeneity is assumed, I have put a note saying that "the terms here used must be understood in a relative sense." But now observe that I am not allowed thus to

qualify the meanings of my words. On p. 227 Prof. Ward says that "spite of this Mr. Spencer, in an earlier foot-note, cuts away the ground from under his own feet by bargaining that 'the terms here used must be understood in a relative sense.'" So that I have thrust upon me an assumption which I have never made, and I am not permitted to say that I do not make this assumption!

Says Prof. Ward on p. 221 of Vol. 1:—"We now find ourselves confronted, as the complete theory requires, by the whole universe in 'a diffused imperceptible state'" (the tacit allegation being that a "diffused imperceptible state" implies homogeneity, which it does not). The nearest approach to any justification for this description is in § 150 (in past editions), where, *avowedly* as a speculation only, I have supposed the original existence, not of a universal nebulous matter, but of a nebulous matter extending to the limits of our Sidereal System, or somewhat beyond, and have then proceeded to draw inferences concerning the process of concentration. But at the close of the argument I have remarked—"We need not here, however, commit ourselves to such far-reaching speculations." So that again, though I have set aside this hypothetical argument as being concerned with a state of things beyond our knowledge, it is insisted that I shall include it. "You shall not begin with such forms of the proximately homogeneous as we know something about or may reason our way back to, but you shall begin with an infinite and absolute homogeneity": the obvious thought being—"My objections will fail unless you do."

To what a pitch Prof. Ward's antagonism leads him may be judged from the following extract:—

"But so long as we look at things from a purely mechanical standpoint, as Mr. Spencer does, it is difficult to see what ground there is for asserting any increase of complexity at all. Given a certain aggregate of mass-points regarded as a conservative system, and there will be a certain number of possible configurations through which it can pass; but on what grounds, I would ask, is one to be called more homogeneous or more heterogeneous than another?" (i, 226.)

Apparently, then, it is not proper to describe the yelk of an egg as more homogeneous than the chicken which evolves from it! Must we say that there is no structural difference between the two? or, if a difference be admitted, is it that the words homogeneous and heterogeneous do not express one of its characters? Or it is that this common-sense distinction must be excluded from higher ranges of thought? Must we accept Prof Ward's dictum respecting "the utterly unscientific and unphilosophical phrase 'indefinite, incoherent homogeneity'" (p. 225)?

The above quoted passage strikes me as somewhat impolitic, since, in a measure, it serves as a test of his reasoning at large, and shows that in pursuance of his aims he is prepared to ignore the meanings of words or else reject the words altogether.

Something must be said concerning one further matter. The

unwary reader, and even the critical reader (as a review article has shown me) if left with no guidance save that of Prof. Ward, will think that I have fallen, in one place at least, into an unquestionable inconsistency of a serious kind. Prof. Ward writes:—

"He illustrates the well-known, but for his argument somewhat anomalous, fact that in general 'simple combinations can exist at a higher temperature than complex ones,' in other words that chemical stability decreases as chemical complexity increases. . . . Now as all ponderable matter is in some chemical state or other, and as the half of our evolutionary formula relates to re-distribution of matter, this fact—that chemically the more homogeneous matter is the more stable—surely cuts a monstrous cantle out of the best of Mr. Spencer's realm. I say the best, for here, at any rate, the terms homogeneous and heterogeneous are strictly applicable. The strange thing, however, is that when, in a subsequent volume of his philosophy, Mr. Spencer comes to treat of the evolution of organic life, this instability of the *heterogeneous* becomes the mainstay of his argument." (i, 231–2.)

Were I at a loss for a conclusive reply, I might urge that since the law of evolution, as everywhere represented by me, is a law of the re-distribution of matter and motion within sensible aggregates, and not as a law of re-distribution within their insensible molecules, it might suffice for its establishment were it proved applicable to the first without taking any note of the last. But I have no need to make any such qualification. There is a three-fold reply which disposes absolutely of his criticism.

First, he has ignored entirely the distinction between simple and compound evolution, though he had before him a chapter setting forth this distinction. It is there explained that evolution is primarily an integration of matter and dissipation of motion, and that under conditions which permit the process to go on rapidly, no other changes take place: the evolution is simple—as instance that of a crystal. It is further explained that when, contrariwise, the matter is such, and the rate of integration is such, that there continues a partial mobility among the concentrating units, there arises that secondary re-distribution which constitutes the change of the homogeneous into the heterogeneous. Ignoring this fundamental distinction, Prof. Ward has assumed that chemical units are aggregates which can present this secondary re-distribution; whereas, as he knows, they are aggregates suddenly formed and, if considered as evolved, can exhibit only that simple evolution seen in the integration of matter and dissipation of motion: the contrast between homogeneity and heterogeneity cannot arise.

In the second place, he has confounded two utterly different meanings of the word "instability." It is not alleged by me that a homogeneous aggregate is, in virtue of its homogeneity, more likely to be overthrown or destroyed by some external force than any other aggregate. My allegation is that its component parts cannot maintain their relations to one another—are unstable in the sense that they must undergo re-arrangement—must lapse into a heterogeneous arrangement. Surely the multitudinous examples given make this clear. External forces, when referred to, are contemplated as causes for

change of structure and not as causes of destruction. But the chemical stability which Prof. Ward names as characterizing the more homogeneous kinds of matter, and the chemical instability characterizing the more heterogeneous kinds, refer to their respective liabilities to be decomposed or dissipated by incident forces exceeding certain amounts.

And then, in the third place, Prof. Ward assumes that along with the assertion that the homogeneous is unstable, I necessarily make the assertion that the heterogeneous is stable, or at any rate relatively stable. Nowhere have I said or implied any such thing; but, contrariwise, have perpetually asserted and illustrated the truth that instability characterizes the heterogeneous as well. Already in the sentences quoted above from § 149 this is clearly shown, and it is again twice over shown in § 163, where it is said "that the homogeneous must lapse into the heterogeneous, and that the heterogeneous must become more heterogeneous," and where it is said of a force that it "turns the uniform into the multiform and the multiform into the more multiform." Moreover at the opening of the chapter on "Equilibration," it is implied that the continuous lapse into greater heterogeneity can never cease until equilibrium is reached. I do not remember that I have anywhere expressed an opinion respecting the relative instabilities of the two states. But very many of the cases given, and very many of the incidental remarks, especially in the chapter on "The Multiplication of Effects," might be held to show that the original proclivity of the homogeneous towards the heterogeneous is equalled, if not exceeded, by the proclivity of the less heterogeneous towards the more heterogeneous.

Thus Prof. Ward's triumphant criticism involves a triple mistake. Molecules of matter, if regarded as aggregates, are not aggregates capable of undergoing that compound evolution which is in question. The instability which the doctrine contemplates is not the external instability to which he refers, but an internal instability. And it is nowhere alleged, as he takes for granted, that the heterogeneous is any more stable than the homogeneous: the simple fact being that to formulate and interpret that progressing complexity which all orders of existences display, it is needful to set out with simplicity, since an account of ever-complicating structure which did not begin with the structureless would manifestly be inadequate; and the result is that the structureless state comes into special prominence

Those who wish further to examine Prof. Ward's criticisms will find sundry others dealt with in an article in the *Fortnightly Review* for December 1899. Were I to notice all of them at length, half a volume would be required; for to expose a mis-statement takes much more space than to make it. So far as I have observed, he has throughout followed the course which generally characterizes controversy—that of setting up men of straw and knocking them down.

## APPENDIX D

### THE GENESIS OF GASEOUS NEBULÆ

In an article on "The Nebular Hypothesis," published in *The Westminster Review* for July, 1858, I concluded a somewhat daring suggestion respecting the constitutions of the planets: arguing that the nucleus of each consists of gases reduced by pressure to the density of liquid. In part justification I cited experiments at that time recently made by M. Caignard de Latour, showing that such density had been produced. Some years later the researches of Prof. Andrews established the truth that each gas has a temperature—"the critical point"—above which no amount of pressure can liquefy it, but below which liquefaction can be effected. In the republished version of this article, now contained in Volume I of my *Essays* (where this passage is transferred to the Addenda along with others of a speculative kind), I have referred to the warrant afforded by his discovery, and have repeated my contention that a structure of the kind supposed, naturally arising in the course of concentration, would be in stable equilibrium. I am told that more recently Prof. August Ritter, of Aachen, has propounded a like view, and that two others have since done so: one being Lord Kelvin.

This conception of planetary constitutions (and by implication the constitutions of celestial bodies at large) was specially dwelt upon because it makes comprehensible that explosion of a planet between Mars and Jupiter suggested by Olbers as having originated the planetoids; and I have, in the last-named place, enumerated the ever-accumulating evidence that some such catastrophe once occurred: the most recent piece of evidence being the discovery of Eros, one of the 450 minor planets, which intrudes, as Æthra does, upon the orbit of Mars. Here I refer to this hypothesis because of its bearing on a conclusion set forth in §§ 182, 182*a* of this work, concerning the probable fate of star-clusters. It is there contended that when such clusters reach an advanced stage of concentration, and when, in conformity with Sir John Herschel's conclusion, collisions have happened among their circulating members, and when, as a consequence not recognized by him, there has been a production of gaseous or

nebulous matter spreading throughout the group (shown by Dr. Roberts to be in some cases discernible), an ultimate catastrophe of a tremendous kind is to be inferred. The occurrence of such a catastrophe is suggested by the following comments on the appearance of the great nebula in Orion, and of the Sagittarius region in the Milky Way. They are extracted from Proctor's *Old and New Astronomy.*

"Some vast explosion seems to have taken place in the region from which all these structures appear to spring." (P. 734.)

"The grouping of the great tree-like structures of the Orion Nebula seems to indicate that they have had their origin in a tremendous explosion or series of explosions in the neighbourhood of the trapezium which has sent forth enormous streams of gaseous matter into a resisting medium. If the stars of the trapezium are fragments of the colliding masses, they show no motion which has as yet been detected." (P. 735.)

"The Sagittarius region of the Milky Way referred to above and shown in Plate 27, contains stellar structures which seem to afford evidence of the projection of matter into a resisting medium. As the tree-like forms in the great Orion Nebula and the forms of the structures in the Corona bear witness to explosions on a colossal scale that have taken place below their bright bases, causing a stream of matter to be projected upwards, which stream has subsequently been divided and its branches deflected from their original course by a resisting medium, so the tree-like forms shown in figs. 452 and 453, as well as on Plate 27, afford evidence of the projection of matter into a resisting medium extending through that region of the Milky Way." (Pp. 737–8.)

Here, then, comes in the significance of the hypothesis respecting the constitutions of celestial bodies, referred to above. The first collisions of stars, such as Sir John Herschel inferred must happen in a concentrating cluster (perhaps preceded by collisions among their attendant planets), would, whatever the natures of the colliding masses, generate great volumes of gaseous matter. This, by continually impeding the stars' motions of translation, would negative the establishment of a moving equilibrium among them, at the same time that it entailed a progressive approach to the common centre of gravity and increasing frequency of collisions. Of course if a celestial body has the structure above suggested, then the contained matter, liquid in density but gaseous in form, would produce an explosion unimaginable in vastness and intensity: outer and inner parts of the colliding stars being alike instantly transformed and projected with enormous velocity in all directions. While the component stars of the cluster were relatively far apart, one of these explosions might not seriously shake its other members; but gradually, with increase of the nebulous medium in extent and density, increasing frequency of the collisions, and increasing closeness of the circulating stars, the tremendous impact received from an explosion would probably destroy the structural equilibrium of the nearer ones and cause them also to explode. If now we conceive these stars to be from half a million to a million miles in diameter, each subjecting its gaseous contents, above "critical point" in temperature, to the pressure caused by

gravitation of its enormous mass—if we conceive the explosion of some two such to be propagated by impact to adjacent members of the cluster, we may dimly imagine forces capable of producing a diffused nebula filling the interstellar spaces, and may understand why it should present the appearance of gaseous matter projected through a resisting medium.

Not a little hardihood seems implied by venturing the foregoing speculation. It is, however, to be regarded only as a speculation, purposely excluded from Chapter XXIII and relegated to this Appendix, so that the general argument of that chapter, already speculative enough, might not be rendered still more questionable. I have thought well to set it forth because the aspects of these diffused gaseous nebulæ almost necessitate some such interpretation. If, as is inferred by observers, inconceivably vast explosions are implied, there can hardly be ignored the question—How came such explosions to be possible? There must have existed centres containing the required quantities of matter and the requisite forces. There must have been such relations between the forces and the matter as would explain the observed diffusion. And there must have been occasions for the liberation of these forces. If star-clusters are in course of concentration, and if stars have the internal constitutions described, then we have causes apparently sufficient to account for these tremendous catastrophes. Otherwise they seem inexplicable.

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